THE UNIVERSITY OF ALBERTA

A SIMULATION APPROACH TO

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by

[illegible]

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF BUSINESS ADMINISTRATION

EDMONTON, ALBERTA

SPRING, [illegible]

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A SIMULATION APPROACH TO COST ANALYSIS OF FOREST FIRE DETECTION SYSTEMS

by

© GREGORY ARCHILLE MARTIN

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ABSTRACT

A simulation model for the evaluation of alternative forest fire detection systems is described. An analysis of nine years of fire-weather data and nine years of fire data for the Footner Forest in Northern Alberta was used in the development of the simulation. A three variable fire growth model is developed and described. A Monte Carlo sampling technique is used to generate the values of stochastic variables. Chi-square and Kolmogorov - Smirnov tests were used to substantiate probability distributions for significant variables. As a result the simulation was judged to be realistic with respect to tower and air route operation. A sequential stopping rule was used to reduce the number of simulated fire seasons by testing the mean of the total seasonal cost at a 95% confidence level. An example of how the output from the model can be used to show the relationship between various design configurations and the total cost of fire detection and fire suppression is presented. Also presented is a run-write-up of the model complete with procedures for modifying the design and the input data.

ACKNOWLEDGEMENTS

The author sincerely thanks Dr. Boyd M. Harnden for directing the project, instructing the author in computer programming and simulation and contributing a great amount of time and energy into this study. The author wishes to express his appreciation to Dr. P. Michael Maher for helpful criticism of the manuscript and the initial organization of the project.

The research for this thesis was partially financed by the Forest Protection Branch of the Alberta Department of Lands and Forests. The Department of Lands and Forests is gratefully acknowledged.

The author is also grateful to Mr. R.S. Miyagawa for the unselfish donation of his time and his patience in instructing the author in forest management practices.

The author gratefully acknowledges the personnel at the Alberta Forest Service Depot who were so considerate during the course of this study.

The author sincerely acknowledges his wife, Joanne, for proof reading, typing and offering her encouragement during the entire project.

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CHAPTER 1

THE MODEL: DESCRIPTION, VERIFICATION AND RESULTS

Introduction

This study was undertaken as the first step in a series of research projects on the prevention - detection - suppression - reforestation systems managed by the Alberta Department of Lands and Forests. The primary objective of the study about which this paper reports was to develop, refine and adapt a quantitative decision model to the realities of an operating forest management service so that current techniques may be assessed in terms of their usefulness in improving forest fire detection.

The current state of technology is such that the design of fire detection systems revolves around the effective use of three major system components; these are manned tower, surveillance aircraft, and the general public. A number of attempts have been made to incorporate the use of Management Science techniques into the area of forest fire detection [5] [6] [12]. The work presented here differs in several important aspects:

(1) The model developed is based on actual fire and weather data which was accumulated by the Alberta Department of Lands and Forests for the past nine years. This large volume of data was used to develop probability distributions for use in a Monte

Carlo decision model by utilizing the system of computer programs provided by SPSS [10].

(2) The fire-growth model which was developed was based on published fundamental-empirical research into various forest environmental parameters and the resulting effect on the burning of forest fuels [2]. The model considers the propensity to burn of fuels in the forest, the burning characteristics of four different fuel types and diurnal fluctuation of fire-weather factors[1]. This approach differs from the works in which analytical fire-growth models are developed by fitting curves to data from actual fire histories [12].

(3) The model aids the detection-system designer by providing information about the effectiveness of particular design configurations with respect to fire discoveries and about the overall design performance as measured by total system cost. The model is specifically aimed at the search for a detection design that produces the lowest total cost of the following criterion function:

---

1. The idea for the fire-growth model was germinated by some excellent unpublished work of R.S. Miyagawa and E.V. Stashko of the Forest Protection Branch of the Alberta Forest Service.

(1) $$\text{Total cost} = \begin{matrix}\text{Cost of}\\ \text{Detection}\end{matrix} + \begin{matrix}\text{Cost of}\\ \text{Suppression}\end{matrix} + \begin{matrix}\text{Cost of}\\ \text{Damage}\end{matrix}$$ [2]

(4) In addition, the advice of Mitroff was heeded and a great deal of thought was given to how the work should be validated [7]. Given the previous work done in this field together with the ability to analyze what was judged to be very good empirical data, it was felt that any modeling should pass generally accepted statistical tests for goodness of fit.

A Description of the Model

The Footner Forest of Alberta was chosen as the prototype for a model which could eventually include forests throughout the entire province. Footner Forest consists of approximately 32,000 square miles of water covered and forested lands containing coniferous, mixed wood, lichen-muskeg, and grass fuels. The northern boundary of the forest adjoins the Northwest Territories and the western boundary adjoins British Columbia. The Footner Forest is currently protected by a formal detection system consisting of 19 manned towers and 5 air routes, which are scheduled on both a seasonal and a daily basis, and an informal public system which includes forestry officers, forest personnel, other aircraft, licensees, government officials,

---

2. At the present time data adequate to support the cost of damage is not available; therefore the cost of damage has been excluded in the example of results presented in this thesis.

the general public, and others. The 19 manned towers are composed of 14 within the forest and 5 outside the forest but close enough to discover fires within the forest boundaries.

The simulation model uses the Monte Carlo technique [8]. Experiments have been based on historical data used in a static fashion. For example, no attempt has been made to forecast changes in such parameters as the average number of fires or the average number of fire days per season. However, the design of the model is such that it can be readily changed to handle forecasts as well as historical data if the designer so desires.

The model works in the following manner. A fire season begins. The total number of fires expected during the fire season is computed by the Monte Carlo procedure, i.e., during computation uniform - pseudorandom numbers are generated and compared with an empirical probability distribution in order to determine values assumed by a variable. These fires are then spread throughout the days of the fire season in Monte Carlo fashion. If one or more fires occur on a given day then a location, cause, fuel type, and time-of-day is assigned to each fire in a similar manner. Daily fire-weather factors and visibility are also obtained by the Monte Carlo process. Given the visibility a check is made to see if the fire can be spotted from a fire-tower or from a surveillance aircraft. A fire might be discovered by either a tower or a surveillance aircraft or both. When this is the case the time that the fire burns

until discovery is taken as a minimum of the elapsed time between fire ignition and discovery. A fire might not be discovered by either fire-towers or aircraft. In this instance, the length of time that the fire burns until discovered by a public agency is determined by the Monte Carlo procedure. After having established the length of time that the fire burns prior to discovery it is possible, using the fire-growth model, to compute the size of the fire at discovery. The fire suppression cost is a function of the size of the fire at the time of discovery and is determined by the Monte Carlo method. This general procedure is followed for each day during the fire season. The number of fire seasons examined, during an experimental run under a given set of design conditions, is determined by the sequential sampling - stopping rule described by Naylor [8]. Once the conditions of the stopping rule have been satisfied, results of the experiment are printed and the computer run terminates.

The fundamental logical framework supporting the model is straight forward and is portrayed by the simplified flowchart of Figure 1-1. Although the logic is relatively simple the functional relationships between variables and the interaction of variables in the computer program is complex. A summary of model relationships is presented in Table 1-1.

Armed with this model the designer of forest-fire detection systems retires to his drawing board after having acquired a map

FIGURE 1-1

GENERALIZED FLOWCHART

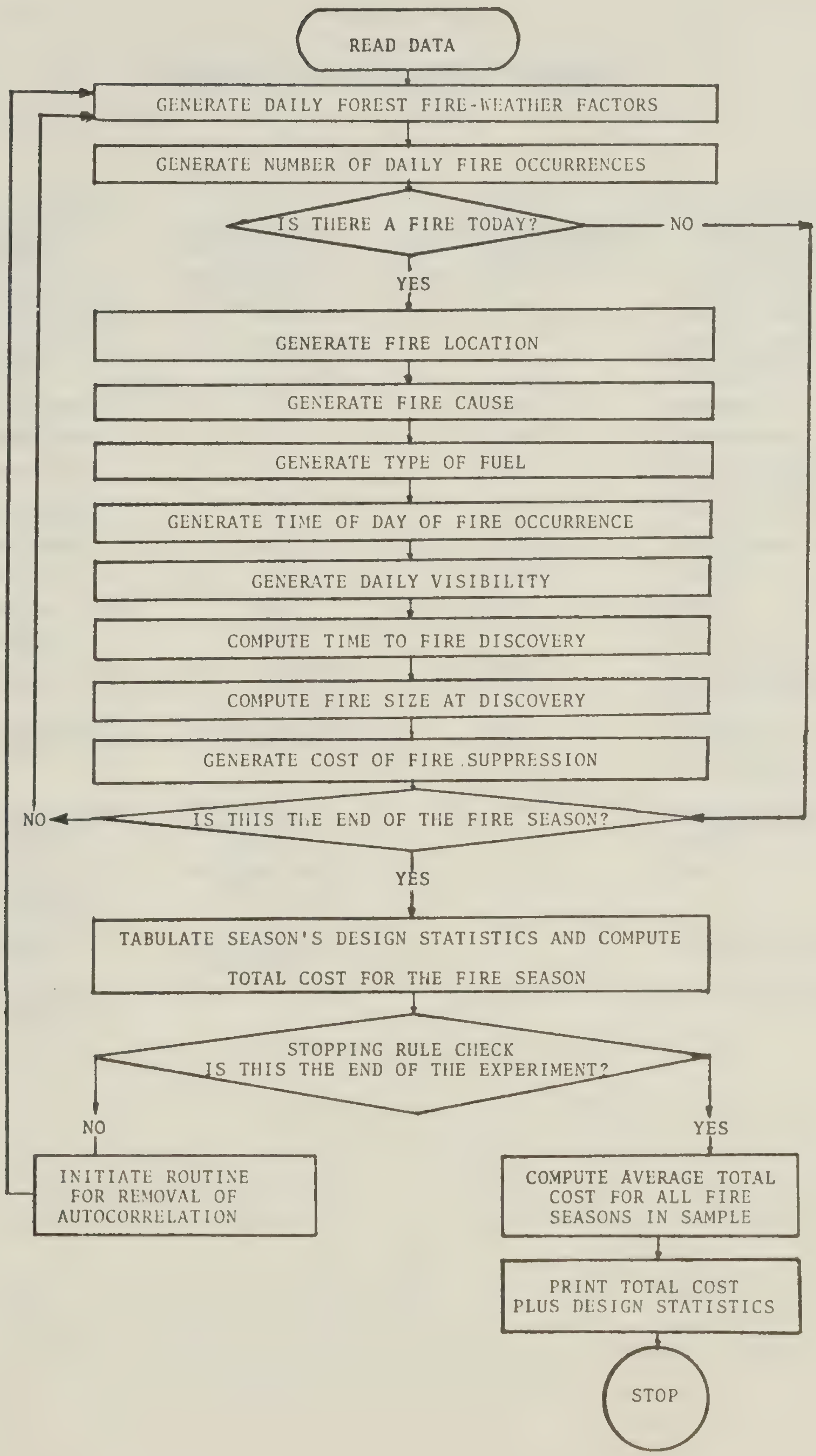


TABLE 1-1

SUMMARY OF MODEL RELATIONSHIPS

The Most Important Probabilistic Variables V	Number Of Possible Values Variable Might Assume	Number Of Probability Distributions Used To Model Variable Behavior	Independent Variables, x, Used To Define The Functional Relationship $V=f(x_1 \ldots x_n)$
1. Number of Fires Per Fire Season	Average of About 50	1	Nine Year Average Seasonal Occurrence
2. Number of Fires Per Day	Upper Bound of About 7	1	Nine Year Averages of Fires Occurring on A Specific Day
3. Spread Index	4	153	Specific Day In Fire Season
4. Buildup Index	5	153	Specific Day In Fire Season
5. Burning Index	5	None	Day, Month, Spread Index, Buildup Index
6. Fire Location	∞	5	Month, Forest District
7. Fire Cause	10	25	Month, Forest District
8. Fuel Type	4	25	Month, Forest District
9. Fire Time of Day	24	10	Cause
10. Visibility	6	4	Spread Index
11. Fire Discovery By Tower	Number of Towers +1	None	Tower Location, Blind Area, Visibility, Fire Location, Time of Day of Fire Start
12. Fire Discovery By Aircraft	Number of Air Routes +1	None	Location of Air Route, Visibility, Fire Location, Time of Day of Fire Start, Time of Day of Flying
13. Time of Burn If Discovered By Tower or Aircraft	Upper Bound of Approximately 12 Hours	None	Minimum of Time To Discovery By Tower or Aircraft
14. Time of Burn If Discovered By Public Agency	Upper Bound of 30 Hours	4	Fuel
15. Fire Size At Discovery	∞ Stratified Into 15 Ranges	None	Fuel, Burning Index, Time of Day of Fire Start
16. Cost of Fire Suppression	11	15	Fire Size At Discovery

of the forest, a protractor, a ruler, and a piece of onion-skin graph paper. While at the drawing board the designer uses his judgment, analytical ability, intuition, imagination, and experience in creating a layout of towers and air routes that he thinks might provide appropriate detection coverage for the forest. He uses his ruler to obtain the map coordinates of each tower location and to measure the length of each leg of each air route. He uses his protractor to measure the angle that each leg of an air route makes with the horizontal, see Figure 1-2. If a "seen-area" map is available the designer uses the piece of onion-skin graph paper to estimate the amount of blind area within each of the twenty segments that make up the maximum observable area of a fire tower, see Figure 1-3. If a "seen-area" map is not available blind area data is obtained from field reconnaissance or from a topographic map.

Physical characteristics with respect to location of towers or air routes are not the only design factors which the designer might wish to investigate or control. For example, the designer might wish to establish policies with respect to actual operation of the system. For instance he might wish to fly his air routes once, twice, or three times a day or he may simply wish to vary the starting time of air surveillance. The model allows the designer to choose from a reasonably realistic set of management policies, or decision rules, and to investigate the results obtained through the implementation of a chosen combination of policies acting in

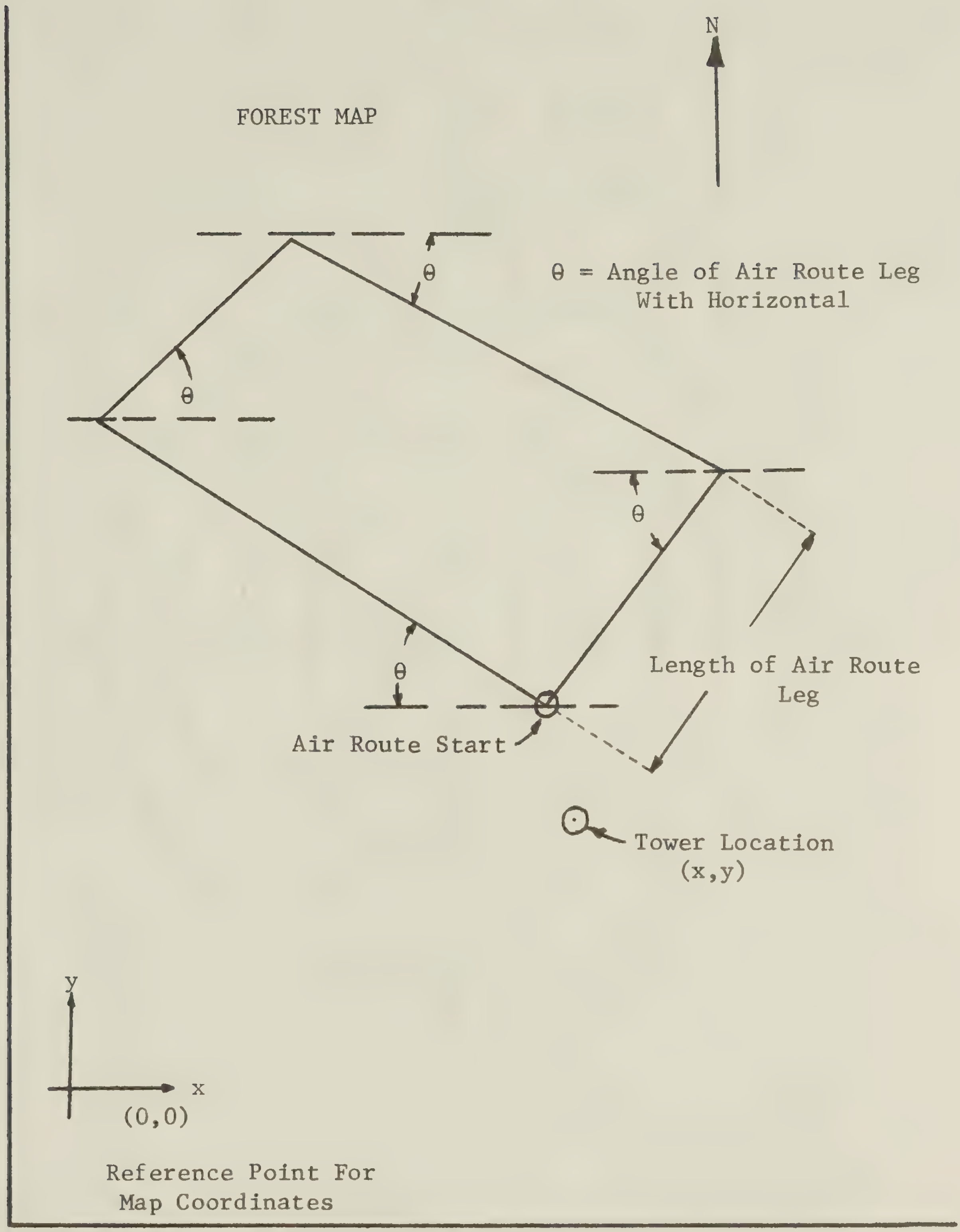


FIGURE 1-2

EXAMPLE OF DESIGN LAYOUT

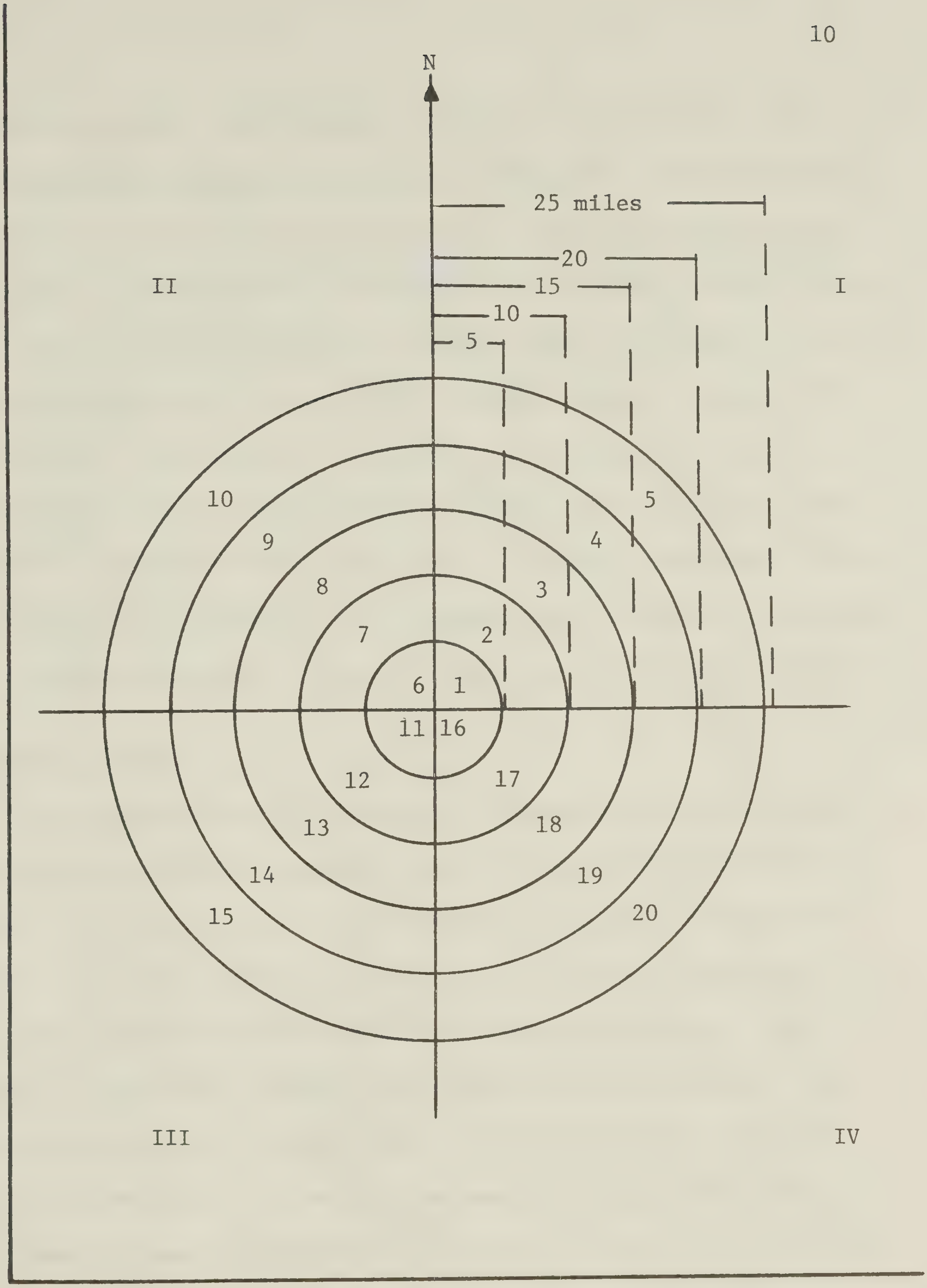


FIGURE 1-3 PARTITIONING OF FIRE TOWER OBSERVABLE AREA

conjunction with a given design. Decision rules with which the designer might experiment are shown in Table 1-2. After preparing a design and selecting a set of decision rules the designer uses the model to experimentally investigate the behavior of his creation. The computer output produces an average total cost of fire detection and fire suppression for any given physical design - decision rule combination. In addition, information is provided with respect to the effectiveness of tower placement and air route location. This provides the designer with guidelines for layout improvement. Also, the output is presented in such a manner that statistics with respect to important variables are readily discernable and easy to analyze.

Goodness of Fit

As mentioned previously the Footner Forest is presently protected by a formal detection system consisting of 19 manned towers, 5 air routes, and a diverse public system. The approach used to test the model was to run it under what was understood to be those management operating policies which produced the nine years of data used to develop and operationalize the model. The simulated output was compared with the historical data to test the hypothesis that the set of data generated by the model had the same frequency distribution as the set of historical data. After this verification process, the model was then used to investigate other design configurations.

TABLE 1-2

DECISION RULES AVAILABLE TO DESIGNER[1]

1. Fly each air route once each day during the months prescribed.
2. Fly each air route twice each day during the months prescribed.
3. Fly each air route three times each day during the months prescribed.
4. Fly each air route only if the burning index is equal to or greater than a level prescribed by the designer; for example fly only if the burning index is greater than or equal to 2.
5. Fly each air route only if a fire has been caused by the agency identified by the designer; for example fly only if a fire has been caused by lightning.
6. Fly each air route if the prescribed burning index is equaled or exceeded or if a fire has been caused by a prescribed agency.

---

1. The model has been dimensioned to handle from 0 to 30 towers and from 0 to 15 air routes or any combination thereof. Air routes can be coded so that they will be active only during prescribed months of the fire season. In addition the daily flying schedule is prescribed by the designer.

It was judged that the most important factor with respect to daily operation concerns the decision made by the Fire-Control Officer as to whether or not to operate the air routes. He uses his judgment and experience with respect to interpretation of fire-weather conditions in the forest in making the decision. If forest conditions are extremely hazardous, or if settlers have been clearing and burning land, or if lightning storms have moved through the forest he will probably operate the air routes. It is this decision process against which the model was tested. Given the functional relationships described in Table 1-1, it was judged that the most important variables to test for goodness of fit were cause, fuel, visibility, fire size at discovery, fire suppression cost, and overall frequency of discovery by towers, aircraft, and public agency. The output was designed for easy analysis of these variables. It is worth pointing out that goodness of fit tests for the cause, fuel, and visibility variables are primarily a test of data, while the goodness of fit tests for fire size, fire cost, and overall frequency of discoveries are essentially a test of the model.

The results of both Chi-Square and Kolmogorov-Smirnov tests for goodness of fit are presented in Table 1-3. It is noted that the overall frequency of discovery by towers, aircraft, and public agency did not pass either test at the 95% confidence level. The actual and simulated overall discovery frequencies are shown

TABLE 1-3

RESULTS OF STATISTICAL TESTING OF SIMULATED DATA

AT THE 95% CONFIDENCE LEVEL[1]

Variable	Variable Passed Chi-Square Test?	Variable Passed Kolmogorov-Smirnov Test?
Cause	No	Yes
Fuel	Yes	Yes
Visibility	Yes	Yes
Fire Size at Discovery	No	Yes
Fire Suppression Cost	Yes	Yes
Overall Frequency of Discovery by Towers, Aircraft, and Public Agency	No	No

1. The sample sizes were 2649 for Fuel and 2667 for all others. The design alternative used was 19 towers and fly if the burning index is greater than or equal to 2 or if a fire has been caused by lightning.

TABLE 1-4

COMPARISON OF HISTORICAL AND SIMULATED FREQUENCY OF DISCOVERY BY

TOWERS, AIRCRAFT, AND PUBLIC AGENCY

	Historical Frequency of Discovery	Simulated Frequency of Discovery Fire Sample Size - 2667
Towers	41.8	40.3
Aircraft	18.7	16.7
Public Agencies	39.5	43.0
Total	100.0	100.0

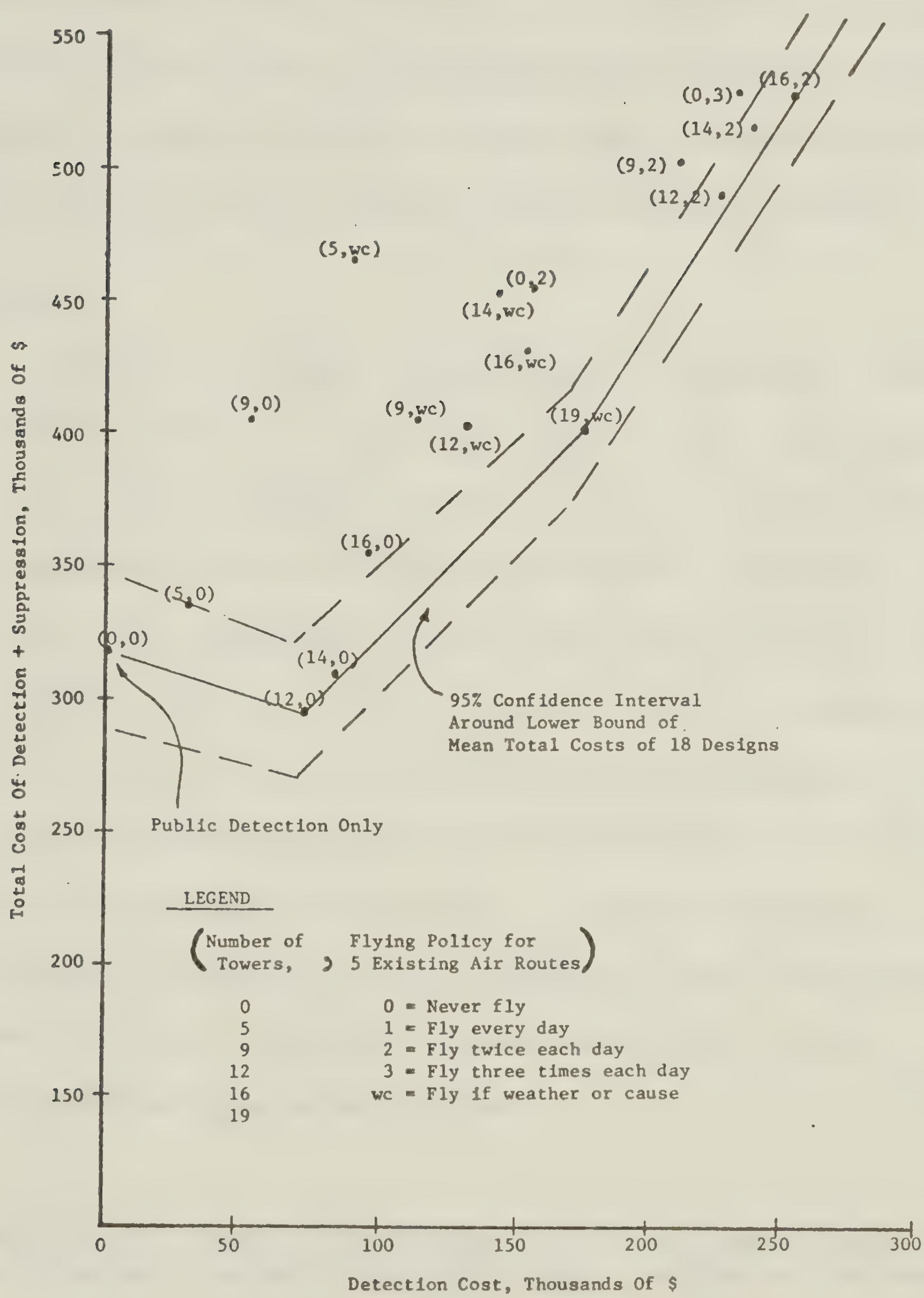
in Table 1-4. It was concluded that the difference between these two frequencies could be explained in the aircraft scheduling procedure and the aircraft flight paths. It would appear that the aircraft routes actually find more fires than what is predicted by the model because of the pilot's flexibility in his course direction and his current information as to where fires may exist based on the route he flew yesterday or storm movements from the previous night or settlement activity. Some of the difference could also be due to some behavioral aspects of fire reporting about which no empirical evidence exists. Nevertheless, the overall goodness of fit of all but one of the most important variables of the model, at a large sample size (N greater than 2000) and the visual closeness of the actual and simulated frequencies of discovery attests to the validity of the model.

Example of Results

The model was tested using data from the Footner Forest. A total of 18 experiments were performed under various design-policy combinations. A typical computer run using an object deck requires between 72 and 99 seconds of CPU time on an IBM 360/67 computer and costs about $40.00 at current commercial rates. The result of the computer runs is presented in Figure 1-4. Detection cost includes charges of $6,000.00 per year per tower and $48.00 per flying hour. Fire suppression cost includes the total of fire

FIGURE 1-4

Results of Footner Forest Analysis



identification of potentially suitable detection strategies. The model's only purpose is to provide decision makers with a method for easily evaluating various detection strategies. Furthermore, the results cannot be directly related to the detection strategy employed in another forest. However, it is important to realize that the model can be easily adapted for use in different forests. Accordingly, the implications of a large number of different detection strategies can be readily explored in many different forests.

Conclusions

The results strongly suggest that a quantitative decision model may be successfully refined and adapted to the realities of an operating forest management service. It may be further concluded that a quantitative decision model may be useful in improving the art of forest fire detection. However, this later conclusion must be more fully considered. A well designed program of implementation must be undertaken to assure success in operating the model. Such a program of implementation would be directed toward (1) formally evaluating the usefulness of the model in terms of improving the art of forestry management and (2) identifying those factors which are important for the successful introduction of such a model in an operating forest management service.[4]

---

4. A paper by P.M. Maher, B.M. Harnden, and G.A. Martin has been prepared in order to describe such a program of implementation.

Further steps in the quantification of forest fire detection and suppression are judged to be essential. First, the importance of continuing the work being done to establish values for public lands is clear [1] [11]. These efforts may be furthered if serious attempts are made, with the aid of the decision model described in this thesis, to examine the implications of various evaluation strategies. Second, the unexpected results obtained from the analysis of the existing detection system in the Footner Forest would suggest that an analysis of the fire-prevention subsystem be undertaken in order to examine the relationships between this subsystem and the public agency portion of the existing fire detection systems. Finally, now that a comprehensive model is available which facilitates a better understanding of the overall system, it may be possible to circumvent some of the complexities of the present model to develop useful analytical models which may lead to identifiable optimal detection strategies.

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CHAPTER 2

BACKGROUND TO THE STUDY

Development of a Study Design

The Faculty of Business Administration and Commerce at the University of Alberta in Edmonton has acquired a number of faculty members who have the interest and necessary technical skills to play an important role in the development of Canada and in particular the Province of Alberta. In an attempt to realize the potential of this new faculty, a series of meetings was held with interested business and government organizations.

One series of meetings was held within the Department of Lands and Forests of the Province of Alberta. These meetings culminated in a research agreement between the Department of Lands and Forests and the Faculty of Business Administration and Commerce.

The research agreement was an open ended agreement in that the department agreed to support an unspecified research project. As a result, a number of strategy meetings were held among key personnel of the Department of Lands and Forests and the Faculty of Business. The purpose of these meetings was to identify key personnel that would be interested in participating in a study, to set out some general guidelines as to what the project should accomplish and to identify possible areas open to study.

During the period from April 26 to May 20, 1971, G.A. Martin, a graduate student in the Faculty of Business Administration and Commerce, gathered information on all aspects of the Alberta Forest Service Fire Protection Branch in an effort to define the area of research. Sources of information were interviews with Mr. C.F. Platt, Supervisor of the Fire Control Section; Mr. C.S. McDonald, Fire Control Officer; Mr. W.J. McLean, Supervisor of the Weather Section; Mr. J. Niederleitner, Fire Control Technician; and Mr. G.H. Deans, Fire Control Dispatcher.

Interviews were also conducted with Mr. S.R. Hughes, Head of the Forest Protection Branch and Mr. H.M. Ryhanen, Head of the Administration Branch of the Alberta Forest Service; and Mr. J. Griegel, Research Officer with the Canadian Forestry Service in Edmonton. Also included as information sources were numerous papers and studies located in the Department of Lands and Forests Library. Three more meetings were held in the Spring of 1971, on April 27, May 5 and May 19. Professors B.M. Harnden and P.M. Maher along with Messrs. D. Cauvin, Section Head of the Economics Section of the Timber Branch; R.S. Miyagawa, Supervisor of Fire Research for the Forest Protection Branch; and G.A. Martin met at the University of Alberta. The purpose of these meetings was to discuss projects applicable to the Alberta Forest Service.

It soon became apparent from these meetings and discussions that there was a high degree of interdependence among the different projects being considered. For example, analysis of a suppression

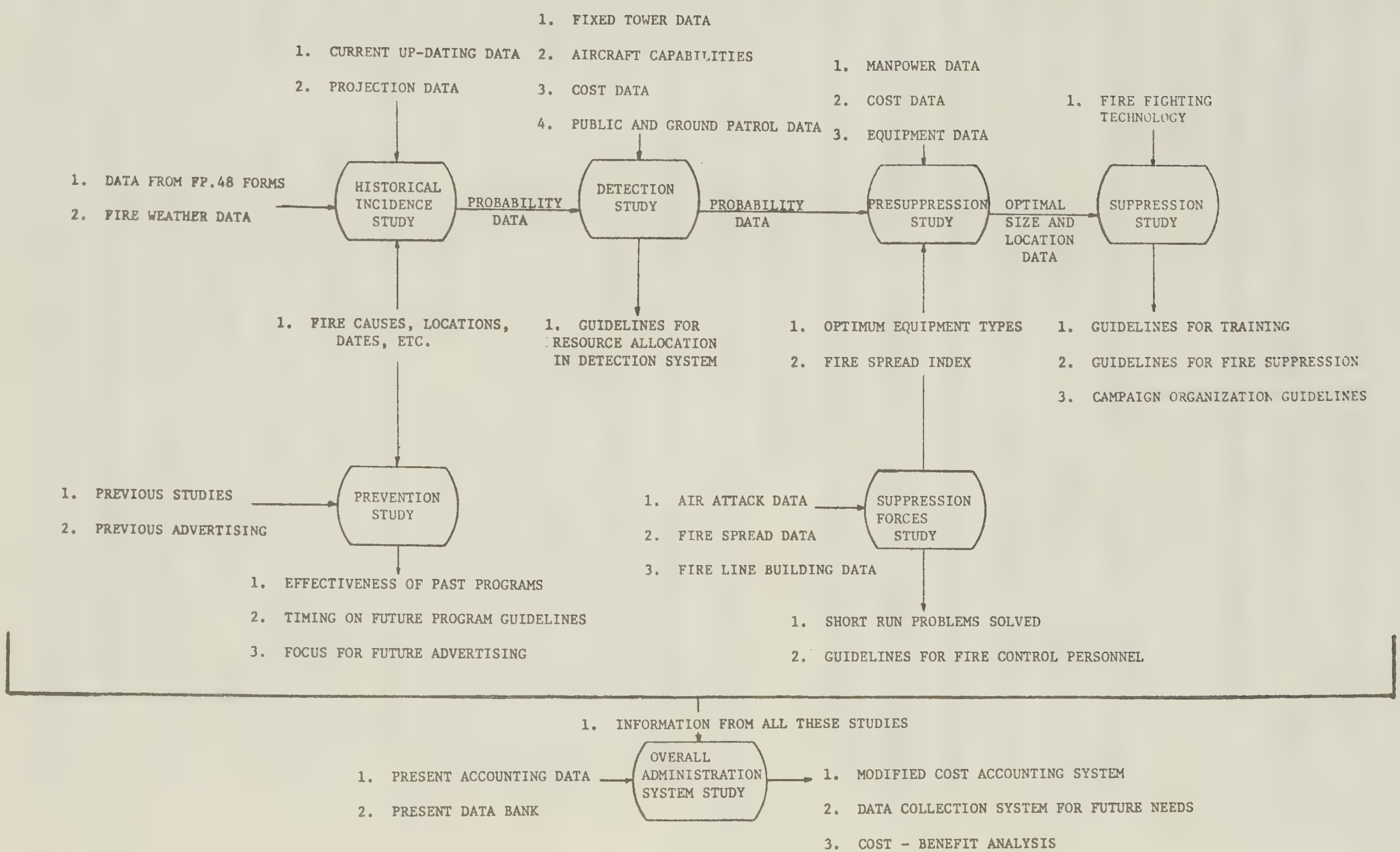
system cannot be done without prior knowledge of the detection system and the size of the fires at the time of initial attack. A second area of concern involved the long term implications of the research proposal. Ideally the project sought was one that would lay the ground work upon which future research could be based.

On the advice of Messrs. Miyagawa and Cauvin, a proposal was drafted on May 25, 1971 and recommended by Mr. S.R. Hughes and approved by Mr. R.G. Steele, Director of Forestry, shortly thereafter. The purpose of the proposal was to outline a sequence of research studies that could be carried out by the Alberta Forest Service. The primary objective set out in the proposal was to provide the management of the Alberta Forest Service with a clearer picture of alternatives available for strategic decision making. The proposal which was recommended began with a study of fire incidence and was to proceed through the sequence shown in Figure 2-1.

Figure 2-1 represents a schematic of the possible research studies recommended in the May 25 proposal and shows the order the studies should assume. The schematic begins with a study of forest fire incidence. This study could be followed by either a study on fire prevention or fire detection. The output from the historical fire incidence study would be required as input for both the prevention and detection study. Output from the detection study would be required for the proposed presuppression study and output from the presuppression study could be used in the suppression study. A separate study of

FIGURE 2-1

SEQUENCE OF RECOMMENDED RESEARCH STUDIES



suppression forces would provide input to the presuppression study. The overall administration system study would be done last. Output for the other six studies would provide information required to conduct this last study.

The previously mentioned problem of interdependence among the 7 proposed studies was minimized by organizing the planned sequence shown in Figure 2-1. The sequence was arranged so that the results of one project would supply some of the information required to solve the next scheduled assignment. Accordingly, as one study is finished, the next is brought into much sharper focus because of the new information supplied from the completed assignment.

The research began with a study of fire incidence in Alberta. The objective of this study was to arrange and program existing fire data into a system whereby meaningful analysis could be done on forest fire causes, occurrences, growth, etc. Under the guidance of Mr. R.S. Miyagawa, systematic analysis of Alberta's fire and weather data from 1961 to 1969 was undertaken. The data was analysed using an IBM 360-65 computer and the Statistical Package for the Social Sciences (SPSS). In addition, two field trips into the Whitecourt and Rocky-Clearwater Forests were made to gather information on how the fire control and detection systems operate in Alberta. The study of fire incidence was essentially completed once the data was organized and the computer was providing statistical information on Alberta forest fires. The formal fire incidence study was completed

by mid August and Miyagawa is currently updating the data bank with fire data from the 1970 and 1971 seasons and extracting meaningful statistics on Alberta forest fires. The formal research proceeded from the incidence study to a study of a fire detection system. Professor B.M. Harnden and G.A. Martin began programming a simulation model for the detection system in the Footner Forest in Northern Alberta. The objective was to develop a general purpose computer simulation which could eventually be used to study the detection system for all of Alberta. The results of the detection study can be used as a guideline in allocating resources and measuring the effectiveness of the present detection methods.

Pre-Requisites to the Model Design

The accumulation and organization of the data required to operationalize a large simulation model is a very time consuming task. Figure 2-2 shows the sequence of main events leading to actual programming of the simulation. Prior to the beginning of this research, the Alberta Forest Service had accumulated fire data for each of the 4,668 fires occurring in Alberta between 1961 and 1969 inclusive. This data had been transfered from fire report forms onto IBM cards and magnetic tape for use on an IBM 7070 computer. There were 67 different pieces of information about a fire available from the fire report forms. A list of this information is shown in Table 2-1. The first step was to transfer the data from the IBM 7070 tape to a nine track tape for

FIGURE 2-2

A TIME SEQUENCE OF KEY EVENTS

KEY EVENTS		PRELIMINARY & INTERMEDIATE REQUIREMENTS
	APRIL	
Research offer	2	
Preliminary meeting	13	Broad problem areas outlined where research may be applicable
Offer accepted	15	
Research started	26	
2nd meeting of U of A staff and forestry officials	27	Start of literature survey and indoctrination period
	MAY	
3rd meeting of U of A staff and forestry officals	5	Initial research proposal written and reviewed by Miyagawa and Cauvin. Proposal modified
4th meeting of U of A staff and forestry officials	19	Modified proposal reviewed and remodified. Final draft of research proposal written for submission to Alberta Forest Service, approved by R.G. Steele
Research Proposal submitted to Alberta Forest Service	25	
FIRE INCIDENCE STUDY BEGINS		Introduction to IBM system and review of existing tape files and data. Reports written to explain and request computer usage and time required.
Organization of fire data on IBM 7070 tape begins	28	
	JUNE	
Computer usage report issued also time requested for IBM-360	2	Fire data reorganized and examined
Fire data transfered to IBM-360 tape	3	SPSS program being written to create an SPSS file "Forstudy"
Computer programs to create SPSS file written	18	Literature was studied to decide which variables to select in a simulation model for detection study
	JULY	
SPSS file FORSTUDY created	15	Cross tabulations were programmed to aid in determination of variables needed for detection study.
Organization of weather data for transfer to 360 tape begins	16	Weather data investigated and 7070 tape reorganized. Intermediate programs to transfer weather data by forest used to reduce computer requirements.
	AUGUST	
		Footner Forest data segregated onto an IBM-360 tape.
SPSS file WEATHER created for Footner Forest weather data	12	Cross tabulations were programmed to accumulate probability distributions on fire variables and weather variables.
FIRE DETECTION STUDY BEGINS		Flow chart drawn for a detection model using a simulation technique
	SEPTEMBER	
		Footner Forest maps examined
Start of programming of simulation model in FORTRAN IV by C. Martin and B. Harnden	3	Miyagawa supplied consulting service
		Coding and debugging of program
	MARCH 1972	
Footner Forest detection design runs completed		
	APRIL 1972	
Martin's Masters thesis and report for Alberta Forest Service completed.		

TABLE 2-1

A LISTING OF THE VARIABLES IN THE SPSS FILE FORSTUDY

1.	Forest	Forest fire occurred in
2.	District	Ranger district fire occurred in
3.	Year	Year fire occurred
4.	Fireno	Fire number
5.	Lockout	Name of lookout discovering fire
6.	Sizeclas	Size class of the fire
7.	Gencause	General cause of the fire
8.	Specause	Specific cause of the fire
9.	Causecla	Category of people discovering fire
10.	Ownship	Ownership of the land where fire occurred
11.	Legalsub	Legal subdivision of the fire origin
12.	Section	section number of fire origin
13.	Twnship	Township of fire origin
14.	Range	Range of fire origin
15.	Meridian	Meridian east of fire origin
16.	Hrstart	Hour of the day the fire started
17.	Day	Day the fire started
18.	Month	Month the fire started
19.	Disctime	Elapsed time from start of fire to discovery
20.	Repdtime	Elapsed time from fire discovery to reported
21.	Crewstar	Elapsed time from hour reported to crew departure
22.	Crewbegn	Elapsed time from crew departure to initial attack
23.	Control	Elapsed time from initial attack to control
24.	Extngsed	Elapsed time from control to extinguished
25.	Twdvehi	Mileage in two-wheeled drive vehicle
26.	Fwdvehi	Mileage in four-wheeled drive vehicle
27.	Tkedvehi	Mileage in tracked vehicle
28.	Hcopter	Mileage in helicopter
29.	Fixedwng	Mileage in airplane
30.	Walking	Mileage by packing
31.	Other	Mileage by other means
32.	Agency	Category of agency discovering the fire
33.	Ocption	Person to whom the fire was reported
34.	Buildind	Build-up index at closestweather station
35.	Spredind	Spread index at closest weather station
36.	Men	Number of men at initial attack
37.	Dozer	Number of bulldozers on initial action
38.	Pump	Number of pumps on initial action
39.	Tanker	Number of tankers on initial action
40.	Bomber	Number of bombers on initial action
41.	Others	Other equipment on initial action
42.	Soil	Type of soil in initial attack area
43.	Topgphy	General topography of initial attack
44.	Slope	Average slope of initial attack area
45.	Aspect	Direction slope is facing
46.	Type	Type of fire at initial attack
47.	Chacter	Character of fire at initial attack
48.	Maxspot	Maximum spotting distance during initial attack
49.	Cover	Cover type at fire origin
50.	Prifuel	Primary fuel at fire origin
51.	Secfuel	Secondary fuel at fire origin
52.	Amount	Amount of fuel available
53.	Contuity	The continuity of the fuel
54.	Moisture	Moisture in the duff
55.	Genweath	General weather in the area
56.	Ofirewea	Weather over the fire
57.	Windir	Direction of wind at initial attack
58.	Windsped	Velocity of wind at initial attack
59.	Windchar	Character of wind at initial attack
60.	Dissize	Size of fire at discovery
61.	Iasize	Size of fire at initial attack
62.	Primeter	Final perimeter of fire
63.	Nonprotn	Final acreage on nonprotection zone
64.	Crown	Final acreage burnt on crownland
65.	Private	Final acreage burnt on private land
66.	Total	Final total acreage of burn
67.	Costs	Suppression costs in dollars

usage on the IBM 360-65 computer located in the Provincial Data Center in Edmonton. The data was further processed and transfered to the IBM 360 tape by the end of June. Using the Statistical Package for the Social Sciences (SPSS) available at the Provincial Data Processing Center, the data was stored at the Provincial Data Processing Center in an SPSS file called FORSTUDY.

As well as the file FORSTUDY, a file called WEATHER was created. The WEATHER file contained the Footner Forest weather data from 11,246 weather reports. Each weather report contained information on 26 variables. A listing of the 26 variables is shown in Table 2-2.

SPSS was selected because of its availability. It is understandable to people unfamiliar with computer programs and is designed to accomodate ordinal and cardinal values. This is an important aspect since many of the variables involved in forest fires are assigned ordinal values or categorized by qualitative attributes. SPSS allowed the examination of data pertaining to each forest or ranger district independently. The subroutine CROSSTABS was used extensively to examine the relationships between key variables and to obtain frequency distributions from which probability distributions could be calculated. An example of CROSSTABS output is shown in Figure 2-3.

The creation of the SPSS files FORSTUDY and WEATHER has provided the Alberta Forest Service with the capability of analysing many variables pertaining to forest fires with relatively little effort. For example, a simple program consisting of less than twenty-five IBM

TABLE 2-2

A LISTING OF THE VARIABLES IN THE SPSS FILE WEATHER

VARIABLE	DEFINITION
1. Station	Weather station reporting the data
2. Month	Month in which data reported
3. Year	Year in which data reported
4. Day	Day the data is reported
5. Time	Morning or afternoon report
6. Sky	Condition of the sky overhead
7. Weather 1	Rain or types of rain
8. Weather 2	Thunder, hail, smoke or snow
9. Weather 3	Factors affecting visibility
10. Visible	Visibility in miles
11. Temp 1	The wet bulb temperature
12. Temp 2	The dry bulb temperature
13. RH	Relative humidity
14. Windir	Wind direction
15. Vindsped	Wind velocity
16. Gusts	Velocity of gusting wind
17. Cloud 1	High clouds
18. Cloud 2	Middle clouds
19. Cloud 3	Low clouds
20. Cloud 4	Cumulus clouds
21. Cloud 5	Heavy cumulus clouds
22. Cloud 6	Cumulonimbus clouds
23. Grass	Condition of the grass
24. Buildidx	The Build-up index
25. Spreadx	The spread index
26. Remarks	Any general remarks

cards will cross tabulate the time of day of fire start with the cause of the fire. R.S. Miyagawa has used both files in his capacity as researcher.

The sequence leading up to the creation of the SPSS files is shown in Figure 2-4.

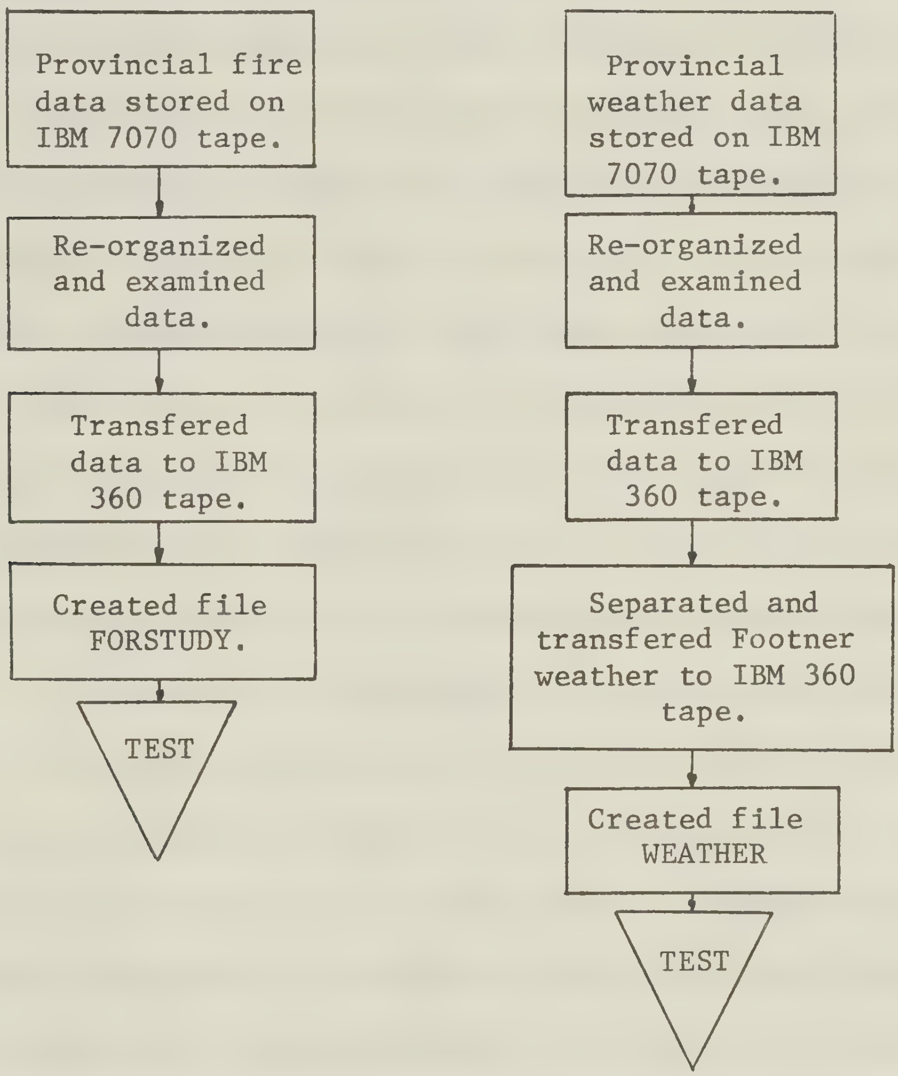


FIGURE 2-4

SPSS FILE CREATION

Relevance and Potential of the Approach

The simulation model described in this thesis can be used as a research base for studies on suppression forces, presuppression, and fire prevention. For example, a study of forest fire suppression would begin with a working knowledge of what sizes of fires the suppression crews are fighting, where the fires are located, what time of day the fires are started, and the rate of spread. The described simulation model calculates the growth rate of every fire, the location of each fire, the time of day of fire start, and the fuel type feeding the fire. Equipped with this knowledge, a designer of suppression forces could expand the model so it incorporates the locations of alternative suppression headquarters. The elapsed time from discovery to suppression crew arrival could be calculated and used as a measure of the effectiveness of the alternative suppression force locations.

A study on fire prevention could also use this model as a base. The model calculates and outputs the cause of each fire and, as further explained in Chapter 4, the growth rate of a fire is a function of the time of day of fire start. A modification of the fire cause probability distribution will affect the growth rate of the fire which directly affects the total cost of the fire. Since the model indirectly describes cost as a function of cause, a researcher could measure the effect of reductions in any of the 10 cause categories recognized by the model. The reduction in cost becomes a measure of the funds to be allocated to achieve the cause reduction objective.

The study of forest fire detection in the Footner Forest is by no means complete with the operation of this model. The model opens doors to many other research areas because the results of other research can be tested in the model. One such research area could be aircraft scheduling. While operating the model as described in Chapter 1, it became clear that the number of fire discoveries by aircraft in the Footner Forest is very sensitive to the time of day the aircraft are flown. For example, the percentage of aircraft discoveries is doubled if the aircraft are flown at 1 p.m. instead of 10 a.m. What is suggested is the need for an optimum scheduling routine which considers the site of fire at discovery.

Another area of research suggested by operating the model lies in the area of the public detection system. As illustrated in Chapter 1, the detection system in a forest is very sensitive to the informal public detector and research in this area could prove extremely rewarding.

Information required for studying a specific problem is unique. The output from this model is cost orientated since the research measured detection effectiveness as a function of total cost of detection plus suppression. This does not limit the model to cost analysis only. The print out can easily be modified to include many other parameters of interest to the researcher.

CHAPTER 3

STATE OF THE ART

Analysis of Detection Systems

Research on Forest Fire Detection Systems has taken four forms over the years. There have been field trials to test and compare alternative detection systems; there have been computer based simulations and analytical models to analyse cost-effectiveness and describe fire growth; there have been national conferences to describe fire problems and set out research guidelines; and there have been research studies on new technological areas such as infrared detection.

The field trial studies have usually been conducted during the fire season to compare aerial detection and fixed tower detection alternatives [4] [14]. Field trials have also been conducted to test the effectiveness of infrared scanners [1] [6] [7]. A field trial is an experiment and as such can be classified as a form of simulation. A typical field trial could leave some of the towers unmanned and replace them with aircraft detection. The substitution of aerial detection for fixed tower detection could then be analysed over the course of the season and a decision made on the effectiveness of the new system.

Field trials are very useful tools for testing some aspects of forest fire detection such as visibility or blind areas. The use

of smoke generators has been quite effective in this regard. Smoke generators are reported to have been used to check on the efficiency of the detection system [4] [14]. In one such report, the forestry official said the use of smoke generators had three objectives:

a) To check on the detection system.

b) To provide data on visibility conditions.

c) To keep up the interest of the observers on routine flights and familiarize new observers with the grid system by locating a smoke and pinpointing it on the map [14, p. 19].

When analysing complete detection systems however, the field trial is too slow and perhaps very costly. It could take several years to accumulate enough information and test enough design alternatives to enable the designer to select the best design. Indeed, the data may be erroneous if the independent variables associated with fires cannot be controlled or accounted for. Factors such as an extremely hazardous season or very wet seasons effect the average results if the average is not calculated over many years. Field trials are very difficult to control. With the invention of the modern computer, the designer has been able to simulate many fire seasons in a matter of seconds. The computer based simulation of forest fires and the accompanying detection systems allows that several design alternatives be compared while the independent variables such as cause, time of day, fuel, etc. all being accounted for. The most impressive simulations

of forest fire detection systems had previously been designed by P.H. Kourtz [8] [10]. The first simulation Kourtz did was for a hypothetical forest consisting of 2,000 square miles divided into three sectors. The design variables were the number of lookouts, number of aircraft flights over areas not protected by lookouts in each sector on each danger class day, and the time of each air patrol. The environmental variables were daily danger index, daily visibility, number of fires in each fire occurrence sector and the time of occurrence of each fire. The objective of the Kourtz simulation was to find the alternative detection system that maximized effectiveness at a given budget level. The measure of effectiveness was average area burned per fire up to the time of detection. The Kourtz study was theoretical and used hypothetical data. Unlike this study, it did not take into consideration diurnal effects of fires burning slowly at night and rapidly during the heat of the day. The Kourtz simulation assumed an average fuel and did not distinguish between fire causes. Table 3-1 illustrates the comparative differences between the Kourtz study and this study. In spite of the aforementioned weaknesses, Kourtz displayed a valid technique in evaluating detection systems. His work provided a basis for this thesis.

A simulation program to evaluate airborne infrared detection was presented in a paper by Kourtz in Missoula, Montana in June, 1971 [10]. This model incorporated a Monte Carlo technique for determining environmental data to operationalize the simulation.

TABLE 3-1

COMPARATIVE CHARACTERISTICS OF THIS STUDY AND THE KOURTZ STUDY

RELEVANT CHARACTERISTICS OF THE KOURTZ STUDY	CHARACTERISTICS OF THIS STUDY
1. Criteria chosen as the Average number of acres burned up to time of detection.	1. Criteria chosen as the minimum total cost where Total cost = Detection cost + Suppression cost + Damage cost[1].
2. Average fuel assumed in growth model.	2. Four fuels were considered in this study.
3. The growth model used was developed to study suppression forces. The Parks Model was driven by the danger index only [15].	3. A growth model was developed for the study area and was driven by time, fuel and burning index.
4. The forest was hypothetical.	4. The forest was real.
5. The air routes were designed probabilistically.	5. Route flying in simulation of actual practice and ability to spot a fire was related to the daily visibility. The route locations were deterministic.
6. Towers were hypothetical and did not have blind areas associated with them. Discoveries were probabilistic.	6. The towers were real and had actual blind areas associated each of them. Discoveries were deterministic.
7. The public could discover every fire based on a poisson distribution.	7. The public found only those fires not detected by aircraft or towers. The elapsed time was calculated using an empirical distribution.
8. The general level of sophistication was low.	8. This model used over 400 probability distributions to simulate the real world.

1. Damage cost was not included because no reliable data exists. However, the simulation is designed to handle such costs. At this time it is possible to use the model to do sensitivity analysis with respect to ascertainment of the range of damage cost that would not change the tentative conclusions reached in the economic analysis. This is an avenue for future research.

Probability distributions were determined from historical data on thunderstorm occurrence time, spread index, fire location, ignition time, hold over time and cloud cover. The growth model used in the simulation was developed by Kourtz and O'Regan and will be discussed in the next section. Also presented by Kourtz at this seminar were examples of existing computer programs to calculate visible area from contour maps and store fire data such as that accumulated on fire report forms. An outline of the later program was given in a December, 1971 publication [9].

A study held at Woods Hole, Massachussetts, July 17 to August 11, 1961 under the guidance of the committee on Fire Research of the National Academy of Sciences - National Research Council resulted in a publication of their recommendations and conclusions on fire problems in the United States [2]. Appendix VIII of the report dealt with operations research in forest fire problems. Appendix VIII states: "there is merit in undertaking this report as an initial effort to improve the understanding of forest fire managers on the potentialities of operations research studies and to assist in the recognition of problem areas by operations research specialists". The study committee obviously recognized the usefulness of operations research in studying forest fires. The committee also recognized the need for data to "develop and validate a suitable fire spread model" [2, p. 163]. Professors Shephard and Jewell felt that: "in all cases of data gathering for operations research studies, it

is important to have collections designed to serve precisely the model structure involved" [2, p. 163].

The Woods Hole conference marked the beginning of a new era in forestry problem solving. In 1961, the U.S. Department of Agriculture Forest Service entered into a cooperative agreement with the University of California to develop a long range operations research program in the field of forest fire control systems [3] [5] [13]. The studies done under this program were in the form of mathematical models designed to provide optimal solutions to suppression methods or establish fire growth in a mathematical form that could be used in suppression or detection optimizing routines. Simulation, as a technique in analysing forest fire detection was not used under this program.

The research in infrared detection systems has been headed by S.N. Hirsch, F.H. Madden and R.L. Bjornsen [1] [6] [7]. The study falls under the general heading of Project Fire Scan; a project to determine the capability of infrared systems as a forest fire detector and to determine the application of infrared systems for delineating the perimeter of large fires when smoke obscuration prevents obtaining the intelligence by conventional means [6]. The necessary infrared equipment had been developed by military contract and it was Project Fire Scan's primary objective to determine the probability of detecting targets in timber cover as a function of vertical angle, timber characteristics and fire size.

Field trials have been conducted over various timber canopies and various fire sizes. The preliminary results published by Hirch indicate the infrared detection system could be an economically feasible system of forest fire detection. Infrared detection was not considered in this study. This study was limited to analysing the existing detection system and infrared was not a part of that system. Future research could incorporate infrared once its effectiveness and limitations in Alberta's forests are known.

Fire Growth Models

Several researchers have had a hand in the development of fire growth models. A few of the prominent models will be discussed and compared in this section.

A fire growth model developed by G.M. Parks was designed to predict fire growth during the time interval from attack on the fire until its control [15] [16]. The model took the form of

$\frac{dA}{dT} = G + HT$ where: A is the area burned in acres.

T is the elapsed time in hours.

G is the linear growth rate in acres per hour.

H is the acceleration in acres per hour squared.

Integrating this equation with respect to time:

$$A = GT + 1/2\ HT^2$$

The values of G and H are estimated by fitting curves to actual fire histories for any particular area. Presumably this could be done for

different fire danger indices and different fuels although no literature was found where the model incorporated different fuel types. Although the Parks model was not specifically designed to model a fire from start until detection, it has been used for this purpose.

A fire growth model was developed by P.H. Kourtz and W.G. O'Regan using a Monte Carlo simulation technique [12]. The model described a smoldering or creeping ground fire that had an area of less than 0.05 acres. The model was capable of simulating for a given fuel and weather conditions the expected perimeter location and burning area of a small fire at any time after ignition. A computer program was written to combine data on fuel grid, variable spread rates, persistence times and the optimizing procedure. The fuel grid data was calculated by a Monte Carlo sampling technique and a set of hypothetical fuel distributions. The variable spread rates were determined by fuel type and spread index class for the day. The persistence times were assigned to each ground fuel type for each spread index. The persistence time was defined as the time in hours that a fuel type could sustain fire after the initial spreading fire had burned midway through the grid square. The optimizing procedure incorporated the Dijkstra algorithm to find the shortest time path between each square in the fuel grid. The model was not verified because of lack of data, however, it was incorporated in an infrared detection study design to compare the effectiveness of an infrared system versus a visual system [10].

A geometric model of fire growth was developed by C.E. Van Wagner [17]. This model assumed a burning fire approximated an elliptical shape where: A - area of fire.

a - long semi axis of ellipse

b - short semi axis of ellipse

V - linear rate of spread at the head

u - linear rate of spread at the flanks

w - linear rate of spread at the rear

t - time since ignition

(1) $A = \pi ab$

(2) $a = (v + w)t / 2\pi$

(3) $b = ut$

Therefore the area

(4) $A = \frac{\pi}{2} (v + w)ut^2$

The growth rate of the fire is then expressed in the form of a velocity component and an acceleration component. The velocity component is: $\frac{dA}{dT} = \pi (v + w)ut$

and the acceleration component is: $\frac{d^2A}{dT^2} = \pi (v + w)u$

The model can be used only if values of v,w, and u are known for a given fuel type, danger index and specific burning conditions such as fuel moisture and wind. As is the case with most geometric models, the model depends on a uniform fuel.

A summary of the characteristics of the growth models previously discussed as well as the growth model presented in Chapter 4 is shown in Table 3-2.

TABLE 3-2

A SUMMARY OF FOUR FIRE GROWTH MODELS

CHARACTERISTICS	PARKS	KOURTZ - O'REGAN	VAN WAGNER	HARNDEN - MARTIN
Shape assumed	No assumed shape	Shape determined by model	Ellipse	Circle
Limit to size of fire	No limit	Less than 0.05 acres	No limit	No limit
Motive for design	To measure suppression effects	To measure infrared detection effectiveness	To simplify previous research and show relationship of variables.	To perform a cost analysis on an existing detection system.
Parameters required to drive model.	Historical growth curves of fires in area.	Fuel type, persistence time, spread index, moisture content of fuel, variable growth rate, a grid of fuel mix.	No explicit parameters suggested fuel type, spread index, wind, fuel moisture.	Fuel type, spread index, build up index, time of day of fire start, length of time of burn.
Statistical verification	None	None	None	Passes Kolmogorov-Smirnov goodness of fit when sizes are regrouped. Passes chi square and Kolmogorov-Smirnov when categorized by cost.

References - Chapter 3

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CHAPTER 4

THE FIRE GROWTH MODEL

Introduction

In 1951, a report on the analysis of 36,000 forest fires in the Northern Rocky Mountains was published [1]. Barrows' work was aimed at gaining a better understanding of occurrence, behavior, control, and effects of fire in order to try to answer a fundamental question: What are the requirements for adequate fire control at least cost [1, p. 137]? Since 1951, there has been a tremendous amount of work done in the analysis of prevention-detection-suppression-reforestation systems. However, even with technological developments such as the infrared forest fire detector the economics of the current state of technology is such that the design of fire detection systems revolves around the effective use of three major system components; which are manned towers, surveillance aircraft manned with trained observers, and the general public. A simulation model has been developed to aid in least-cost design of forest fire detection systems within the Province of Alberta. The development of the design model required the use of a fire growth model which provided information so that management of the Alberta Department of Lands and Forests could use the results provided by the simulation model with confidence. The purpose of this Chapter is to outline the approach taken in constructing a computer-based fire-growth model and the results obtained using this model.

Fire growth models of potential usefulness for cost considerations in systems analysis fall into four major categories. These categories include theoretical-physical, geometric, deterministic-analytical, and probabilistic models derived specifically for use in computer simulations. The theoretical-physical models require measurement of physical parameters which exceed the limits of currently existing field data and, therefore, offer a degree of rigor not matched by existing data [3]. Geometric models which assume fire spread according to some well-defined growth law, and take a standard shape such as an ellipse represent the other analytical extreme and are usually not sophisticated enough to provide the precision required for use in a complex systems analysis [8]. The deterministic-analytical model developed by Parks focuses primarily on fire growth during the time interval between initial fire detection and final fire control [7]. What was needed for this study was a fire-growth model which provided a realistic growth in size up to the time of fire detection. The model presented by Kourtz and O'Regan was developed to portray creeping ground fires of a size less than 0.05 acre [4]. The simulation outlined in Chapter 1 required a model applicable to a range of fire sizes extending from less than .25 acre to greater than 500 acres.

Development of the Fire-Growth Model

Given a fuel type, burning index, and the time of day of fire start the growth model computes the size of the fire at the

time of discovery. This information is then used in a Monte Carlo fashion to compute the cost of fire suppression. The development of the growth model is described in detail below. The idea for this approach was provided by Miyagawa and Stashko [5].

The first task was to develop rate-of-spread classifications for Footner Forest fuel types. An available map of fuel types for Footner was broken into the four categories of coniferous, mixed wood, lichen-muskeg, and grass. Table 4-1, provided a guideline for a rate-of-spread classification for Footner [2, p. 40]. In developing the rate-of-spread classification shown on Table 4-2, the following two basic assumptions were made:

(1) That the partitioning of fuel types, as shown on Table 4-2, is reasonable.

(2) That the forested lands of Footner are approximately equally distributed with respect to valley bottom, benchland, slopes, and ridgetops.

Next, the fire-danger rating referred to as the Burning Index, was developed. We assumed that the Burning Index was a function of two other fire-weather indices called the Buildup Index and the Spread Index. These two indices are calculated according to the instructions provided with the set of tables for use at Alberta Forest Service Weather Stations [9]. Daily records of the Buildup Index and the Spread Index have been kept, in Alberta, during fire seasons for the last nine years. SPSS subroutines were

TABLE 4-1

RATE-OF-SPREAD CLASSIFICATIONS FOR ALASKAN FUEL TYPES[1]

Fuel type	Valley bottom		Benchland		Slopes		Ridgetops
	Wet	Dry	Wet	Dry	Southerly	Northerly	
White spruce or birch-spruce	M	H	H	E	E	H	E
White birch or birch-aspen	M	H	H	E	E	H	E
Black spruce	H	E	H	E-F	E-F	H	H
Aspen	M	M	M	M	H	M	M-H
Cottonwood	L	M	L	M	M	M	
Willow-alder	M	M	M	H	H	M	M
Grass	E	F	F	F	F	F	F
Muskeg	M	H	H	E	F	H	E
Tundra	M	H	H	E	E-F	H	E-F

[1]Rate of spread: L=low, M=medium, H=high, E=extreme, F=flash.

Based on BI of 40: 3 m.p.h. wind; 30 percent relative humidity; severity index 8; today's slat moisture content 6 percent.

used to analyse this data [6]. Cumulative probability distributions for the Buildup Index and the Spread Index were developed for each day of the fire season in the Footner Forest. The average fire season in Footner spans a time interval of 153 days, therefore, 306 probability distributions were used, in Monte Carlo fashion, to model the behavior of fire-weather conditions in Footner. Given a daily Spread Index and a daily Buildup Index, as generated by the simulation, the daily Burning Index was determined by a table look-up procedure. Data provided in the Buildup and Spread Index Tables for use at Alberta Forest Service Weather Stations provided a guideline for establishing the relationships shown in Tables 4-3 and 4-4.

TABLE 4-2

RATE-OF-SPREAD CLASSIFICATIONS FOR FOOTNER FOREST - NORTHERN ALBERTA[1]

Fuel Type From Table 1	Corresponding Fuel Type Assumed for Footner Forest	Frequency of Rate-Of-Spread Classification Found in Table 1 L	M	H	E	F	Classification Used for Footner Fuel Type
Black Spruce	Coniferous	0	0	4	3	2	Extreme
White Spruce or Birch-Spruce White Birch or Birch-Aspen Aspen Cottonwood Willow-Alder	Mixed Wood	2	17	10	6	0	Medium
Muskeg Tundra	Lichen-Muskeg	0	2	6	5	3	High
Grass	Grass	0	0	0	1	6	Flash

1. L = Low, M = Medium, H = High, E = Extreme, F = Flash

TABLE 4-4

BURNING INDEX AS A FUNCTION OF SPREAD INDEX AND BUILDUP INDEX FOR THE FOOTNER FOREST DURING THE MONTHS OF AUGUST AND SEPTEMBER[1]

Difficulty Of Control Of Fires Should Increase
As Buildup Index Increases

Forward Rate of Spread of Fires Should Increase
As Spread Index Increases

Spread Index	Buildup Index 0-9	10-25	26-50	51-100	100+
0-1	1-20 Low	1-20 Low	1-20 Low	1-20 Low	1-20 Low
2-9	1-20 Low	1-20 Low	21-40 Moderate	21-40 Moderate	21-40 Moderate
10-19	1-20 Low	21-40 Moderate	21-40 Moderate	41-60 High	61-80 Very High
20+	1-20 Low	21-40 Moderate	41-60 High	61-80 Very High	81-100 Extreme

[1] Values in the Table represent the applicable range of Burning Index. In terms of fire danger 1-20 = low, 21-40 = moderate, 41-60 = high, 61-80 = very high, 81-100 = extreme.

Given the fuel type and Burning Index provided by simulation, the average initial rate of fire spread can be ascertained. The data shown in Table 4-5 was used as a starting point for estimating the fire perimeter increase applicable to the Footner Forest [2, p. 42]. Experiments were run with the design model, continually modifying the values shown in Table 4-5, until a set of data was obtained which produced what seemed to be realistic average initial rates of spread for the Footner Forest. The final set of data which was used to drive the growth model in subsequent analysis is shown in Table 4-6. The values shown in Table 4-6 have been adjusted for diurnal fluctuation by using the information for Alaska Stick as presented on Figure 4-1 [2, p.48]. We were, therefore, able to develop a fire growth model based on fuel type and burning index which produces a different growth rate for each hour in the day. In this sense, the growth model is dynamic. When one examines Table 4-6, it is evident that minimum values of perimeter increase shown on Table 4-5 provided lower bounds for values adjusted for diurnal fluctuation. In order to use the values obtained for fire perimeter increase to compute the size of the fire, in acres, at discovery, the following three assumptions were made:

(1) That the fire burned through a single fuel type that was either coniferous, mixed wood, lichen-muskeg or grass.

(2) That grass fires occurred only during the month of May in the Footner Forest.

(3) That the area of burn was circular in shape and could be computed according to the simple equation derived below.

TABLE 4-5

AVERAGE INITIAL RATE OF SPREAD[1] ACCORDING TO FUEL TYPE, SLOPE STEEPNESS, AND BURNING INDEX AT SITE OF FIRE[2]

Fuel rate of spread type	Slope steepness[3]	Burning index									
		1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
	Percent	Perimeter increase (chains per hour)									
Low	0-10	0	1	1	1	1	2	2	2	3	4
	11-25	0	1	1	1	2	2	3	3	4	6
	26-50	1	1	2	2	3	3	4	4	6	8
	51-75	1	2	3	3	4	5	6	7	9	13
	Over 75	2	3	4	5	6	7	8	10	15	20
Medium	0-10	0	1	1	1	2	2	2	3	4	5
	11-25	1	1	1	2	2	3	3	4	6	7
	26-50	1	2	2	3	3	4	5	6	8	10
	51-75	2	3	3	4	5	6	7	9	13	16
	Over 75	3	4	5	6	8	10	12	15	20	25
High	0-10	0	1	2	3	4	5	6	8	9	12
	11-25	1	1	3	4	6	7	9	11	13	17
	26-50	2	2	4	6	8	10	12	16	18	24
	51-75	3	3	6	9	13	16	19	25	28	38
	Over 75	4	5	10	15	20	25	30	40	45	60
Extreme	0-10	1	3	4	5	6	8	10	13	16	19
	11-25	1	4	6	7	9	11	14	19	22	27
	26-50	2	6	8	10	12	16	20	26	32	38
	51-75	3	9	13	16	19	25	32	41	50	60
	Over 75	5	15	20	25	30	40	50	65	80	95
Flash	0-10	1	5	12	15	19	24	30	37	46	57
	11-25	1	7	17	21	27	34	42	52	65	81
	26-50	2	10	24	30	38	48	60	74	92	114
	51-75	3	16	38	48	60	76	95	117	146	181
	Over 75	5	25	60	75	95	120	150	185	230	285

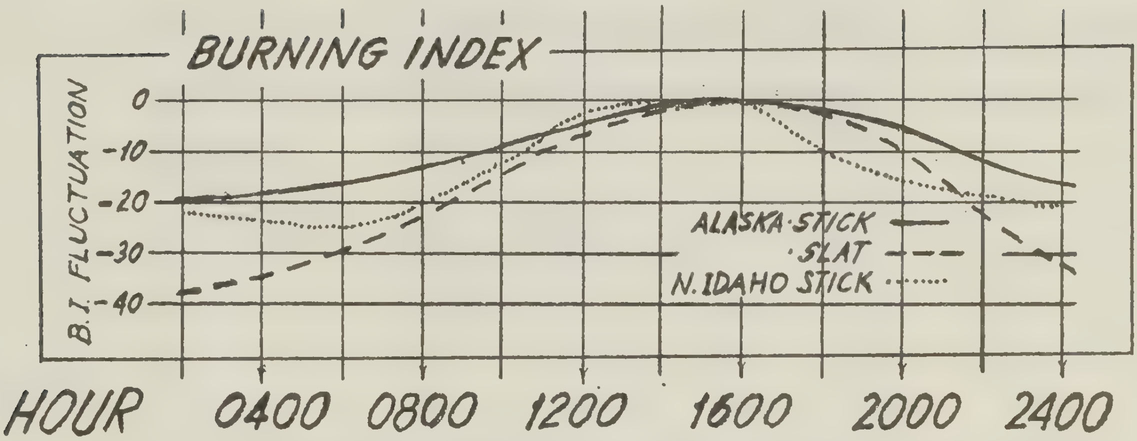
[1]Average initial rate of spread refers to perimeter increase between discovery of fire and first attack. This rate of spread may be anticipated during the first 4 to 5 hours.

[2]Table based upon study of 2,955 fires in National Forests, R-1, 1936-44. Values for very high and very low burning index have been estimated.

[3]General descriptions used in slope descriptions are: Level, 0-10 percent; Gentle, 11-25 percent; Moderate, 26-50 percent; Steep, 51-75 percent; Very steep, over 75 percent.

FIGURE 4-1

BURNING INDEX FLUCTUATION VS. TIME



C = Perimeter increase in chains per hours

A = Size of fire at discovery in acres

t = Time in hours

(1) $C = 2\pi r$

(2) $A = \pi r^2$

(3) $A = \pi \cdot (C/2\ )^2$

(4) $A = C^2/4\pi$ square chains

(5) $A = 4356C^2\ /4\pi$ square feet

(6) $A = C^2\ /\ 40\pi$ acres

If a fire burned for t hours prior to discovery the total area burned is computed according to equation 7.

(7) $A = \sum_{i=1}^{i=t} C_i^{\ 2}\ /\ 40\pi$

For example refer to Table 4-6. If a fire started at 0500 hours, in a coniferous fuel, on a day with a burning index that reached a maximum in the 21-40 range, and burned 2 hours prior to discovery the size of the fire at discovery would be computed according to equation (7), above, as follows:

$$A = (8.1)^2 / 40\pi + (8.2)^2 / 40\pi = 1.06 \text{ Acres}$$

Results

The fire growth model is a small portion of a computer program developed to aid in the design and evaluation of forest fire detection systems. As outlined in Chapter 1, the model was validated by comparing results obtained from a computer run, designed to model the present operating decision and physical processes existing in the Footner Forest, with statistics obtained from analysis of nine years of historical data. Table 4-7 shows the results obtained with the fire-growth model when it was used to compute the size of the fire at discovery for 2,667 fires spread over the 7,956 days of 52 fire seasons. The distribution of fires within fuel categories is shown in Table 4-8. The visual fit is quite close. When the fire sizes are grouped into categories as shown in the lower portion of Table 4-7, the results obtained from the fire growth model pass the Kolmogorov-Smirnov test for goodness of fit. This standard statistical procedure provides a test of the hypothesis that the

TABLE 4-6

AVERAGE INITIAL RATE OF SPREAD ACCORDING TO FUEL TYPE,

BURNING INDEX, AND HOUR OF DAY FOR FOOTNER FOREST[1]

Fuel Rate of Spread Type	Burning Index	Perimeter Increase In Chains Per Hour of Day																							
		0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Mixed Wood (Medium)	1-20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	21-40	2.5	2.5	2.5	2.6	2.6	2.7	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.5	3.5	3.4	3.3	3.2	3.1	3.0	2.7	2.5
	41-60	8.0	8.0	8.0	8.2	8.2	8.4	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.0	10.0	9.8	9.6	9.4	9.2	9.0	8.4	8.0
	61-80	12.0	12.0	12.0	12.2	12.2	12.4	12.6	12.8	12.9	13.0	13.2	13.4	13.6	13.8	14.0	14.0	14.0	13.8	13.6	13.4	13.2	13.0	12.6	12.0
	81-100	18.0	18.0	18.4	18.6	19.0	19.4	19.6	20.0	20.4	20.8	21.2	22.0	22.4	22.6	23.0	23.0	23.0	22.6	22.0	21.4	21.0	20.6	20.0	19.0
Lichen - Muskeg (High)	1-20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	21-40	5.5	5.5	5.5	5.6	5.6	5.7	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.5	6.5	6.4	6.3	6.2	6.1	6.0	5.7	5.5
	41-60	11.5	11.5	11.8	12.1	12.4	12.7	13.0	13.3	13.8	14.3	14.8	15.3	15.8	16.3	16.5	16.5	16.5	16.3	15.8	15.3	14.8	14.3	12.7	11.8
	61-80	17.0	17.0	17.2	17.4	17.6	17.8	18.0	18.2	18.6	19.0	19.4	19.8	20.2	20.6	21.0	21.0	21.0	20.6	20.2	18.8	18.4	18.0	17.8	17.2
	81-100	30.0	30.0	30.6	31.0	31.4	31.6	32.0	32.2	32.4	32.6	33.0	33.4	33.8	34.0	34.2	34.6	35.0	35.0	34.2	33.8	33.2	32.4	32.0	31.0
Coniferous (Extreme)	1-20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.6	1.9	2.2	2.5	2.5	2.5	2.2	1.9	1.6	1.4	1.0	1.0	1.0
	21-40	8.0	8.0	8.0	8.1	8.1	8.2	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.0	9.0	8.9	8.8	8.7	8.6	8.5	8.2	8.0
	41-60	37.0	37.0	37.5	38.0	38.5	39.0	39.5	40.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	47.0	47.0	46.0	45.0	44.0	43.0	42.0	39.0	37.5
	61-80	45.0	45.0	45.5	46.0	46.5	47.0	47.5	48.0	49.0	50.0	51.5	52.0	53.0	54.0	55.0	55.0	55.0	54.0	53.0	52.0	51.0	50.0	47.0	45.5
	81-100	57.0	57.0	57.5	58.0	58.5	59.0	59.5	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0	67.0	67.0	66.0	65.0	64.0	63.0	62.0	59.0	57.5
Grass (Flash)	1-20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.6	2.2	2.8	3.4	4.0	4.0	4.0	3.4	2.8	2.2	1.6	1.0	1.0	1.0
	21-40	90.0	90.0	90.4	90.8	91.2	91.8	92.5	93.0	94.0	95.0	96.0	97.0	98.0	99.0	99.0	99.0	99.0	97.5	96.0	94.5	93.0	92.5	92.0	90.1
	41-60	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
	61-80	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
	81-100	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0

1. The upper bound on time limit for burn to which these values were applied was approximately 12 hours

TABLE 4-7

FIRE SIZES AT DISCOVERY AS COMPUTED BY THE FIRE GROWTH MODEL

Size Category Acres	#In Category Produced by Simulation	Percent of Occurrences Expected on Basis of 9 Year Historical Analysis	Percent of Occurrences Computed by Fire Growth Model Sample Size 2,667
Spot	1,047	44.2	39.3
.25 - 1.45	601	18.3	22.5
1.46 - 2.45	152	4.6	5.7
2.46 - 3.45	126	4.4	4.7
3.46 - 4.45	64	1.6	2.4
4.46 - 5.45	40	4.7	1.5
5.46 - 6.45	48	1.2	1.8
6.46 - 7.45	48	0.6	1.8
7.46 - 8.45	9	1.4	0.3
8.46 - 9.45	24	0.8	0.9
9.46 -10.45	11	5.0	0.4
10.46 -25.00	164	5.0	6.2
25.01-100.00	186	4.6	7.0
100.01-500.00	136	3.2	5.1
500+	11	0.4	0.4
Totals	2,667	100.0%	100.0%

Regrouped Frequencies

Spot - 1.45		62.5	61.8
1.46 - 5.45		15.3	14.3
5.46 - 9.45		4.0	4.8
9.46 -100.00		14.6	13.6
100.01 -500.00		3.2	5.1
500+		0.4	0.4
	Total	100.0%	Total 100.0%

TABLE 4-8

DISTRIBUTION OF FIRES WITHIN FUEL CATEGORIES WHICH SERVED

AS A BASIS FOR FIRE SIZE AT DISCOVERY

COMPUTATIONS AS SHOWN ON TABLE 4-7

Fuel Type Category	Number In Category Produced By Simulation	Percent of Occurrence Expected on Basis of 9 Year Historical Analysis	Percentage of Occurrence Computed by Simulation[1]
Coniferous	1,189	44.5	45.0
Mixed Wood	670	20.9	25.0
Lichen-Muskeg	649	23.2	24.0
Grass	159	11.4	6.0
Totals	2,667	100.0%	100.0%

1. Grass fires were generated only during the month of May. When grass fires were generated for each month according to the probabilistic fuel data, the percentage of occurrence computed by simulation was nearly identical to the expected occurrence. However, the size distribution was distorted. This problem could be easily overcome by modifying the grass portion of Table 4-6 for months other than May.

set of data generated by the model has the same frequency distribution as the set of historical data.

Empirical probability distributions relating fire size at discovery to the final cost of fire suppression were obtained through analysis of the nine years of available data. Given the fire size at discovery as computed by the growth model, it was possible to compute, using a Monte Carlo procedure, the cost of fire suppression. The cumulative probability distributions used in computation of fire suppression cost are shown in Table 4-9. The cost results obtained, for 2,667 fires spread over 7,956 days of 52 fire seasons, following the procedure described above are shown in Table 4-10. The results obtained pass both the Chi-Square and Kolmogorov-Smirnov tests for goodness of fit.

Conclusions

A fire-growth model has been developed which provides accurate information, for cost analysis, when used in conjunction with a simulation model constructed to aid in the design and evaluation of forest fire detection systems. Although the fire-growth model was based on operating data applicable to the Footner Forest in Alberta, the approach taken in development is entirely general and can be applied to any forest where both fire-weather data, as obtained from field measurements, and fire data of a general nature are available.

TABLE 4-9

CUMULATIVE - EMPIRICAL PROBABILITY DISTRIBUTIONS RELATING FIRE SIZE AT DISCOVERY TO THE COST OF FIRE SUPPRESSION - FOOTNER FOREST

Fire Size Acres	Cumulative Probabilities Average Costs Used, $ 25	48	268	742	2059	6956	14650	34094	60666	87857	285294
Spot	.203	.428	.698	.820	.987	1.00					
.25- 1.45	.152	.239	.478	.630	.967	.989	1.00				
1.46- 2.45	.087	.130	.260	.303	.825	.868	.955	1.00			
2.46- 3.45	.227	.272	.317	.453	.908	1.00					
3.46- 4.45	.001	.125	.250	.251	.875	1.00					
4.46- 5.45	.042	.043	.168	.251	.834	.959	1.00				
5.46- 6.45	.333	.334	.500	.501	.833	1.00					
6.46- 7.45	.333	.334	.335	.667	1.00						
7.46- 8.45	.001	.002	.143	.429	.715	1.00					
8.46- 9.45	.001	.250	.500	.501	1.00						
9.46- 10.45	.040	.080	.200	.360	.760	.880	.881	.920	.921	.960	1.00
10.46- 25.00	.040	.160	.400	.401	.720	.880	.960	1.00			
25.01-100.00	.001	.087	.174	.348	.739	.740	.870	.957	.958	.959	1.00
100.01-500.00	.001	.002	.063	.188	.438	.563	.751	.939	.940	.941	1.00
500+	.001	.002	.003	.004	.005	.006	.007	.008	.009	.500	1.00

TABLE 4-10

COMPUTED SUPPRESSION COSTS USING OUTPUT FROM GROWTH MODEL AND PROBABILITY DISTRIBUTIONS SHOWN IN TABLE 4-9

Fire Cost Range $	Category Average Used $	Number In Category Produced By Simulation	Percent Of Occurrence Expected On Basis Of 9 Year Historical Analysis	Percent of Occurrence Computed By Simulation Sample Size 2667
No Data[1]	25	402	14.3	15.0
1-100	48	358	13.5	13.4
101-500	268	543	20.9	20.4
501-1000	742	296	12.0	11.1
1001-5000	2059	790	29.3	29.6
5001-10000	6956	114	4.8	4.3
10001-25000	14650	88	2.4	3.3
25001-50000	34094	52	1.6	2.0
50001-75000	60666	1	0.0	0.0
75001-100000	87857	5	0.4	0.2
1000000+	285294	18	0.8	0.7
	Totals	2667	100.0%	100.0%

[1] Small Fires That Resulted In Negligible Suppression Cost

Experiments with the growth model, to date, have indicated that the two fire-weather indicators, i.e., the Buildup Index and the Spread Index, are not sensitive enough to the probable high rate of spread of grass fires during that portion of the year when this vegetation is cured and easily ignited. Further research is required in order to improve our understanding of the spread of grass fires.

References - Chapter 4

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APPENDICES

APPENDIX A

A MODIFICATION MANUAL

The simulation model is programmed in Fortran IV G. The program was run on the IBM 360-67 computer at the University of Alberta computing center, Edmonton. The general operation of the model is shown in Figure 1-1, on page 6.

Data Organization

A listing of the required data is shown in Table A-1. The data deck is set up with the variables ordered in the same sequence they appear in the main program (see the main program listing, Appendix B). Figure A-1 shows the data deck set up. A description of each of the variables used in the data deck set up can be found in the dictionary in Appendix C. Each of the variables in the data deck list, Table A-1, has been categorized as deterministic, stochastic or design. The deterministic variables are calculated and read into the program to make it general in its operation. These variables allow the designer to more easily change the model to apply it to another forest. The stochastic variables are determined by the history of fires and weather in the forest under consideration. They are cumulative probability distributions usually discrete, having a unique value for each category or range of the variable. The design variables are those that represent the physical characteristics of the

TABLE A-1

DATA DECK LIST

SET UP NUMBER	SET UP NAME	VARIABLE TYPE	INPUT FORMAT	NUMBER OF CARDS REQUIRED
1	NREPET	Deterministic	I1	1
2	NAIR	Deterministic	I2	1
3	ZALPHA	Deterministic	F5.4	1
4	IX	Deterministic	I9	1
5	CAU	Deterministic	11F6.0	1
6	COSTT	Deterministic	F10.0	1
7	SPRING, SUMMER	Deterministic	2I2	1
8	ALT 1, ALT 2 ...ALT 10	Deterministic	10A4	1
9	FORES 1,....FORES 5	Deterministic	5A4	1
10	PNFIRE	Deterministic	F10.5	1
11	MATT	Deterministic	I2	1
12	IC	Deterministic	I2	1
13	IB	Deterministic	I2	1
14	NROUTE	Deterministic	I2	1
15	NTOWER	Deterministic	I2	1
16	ISEX	Deterministic	I4	1
17	NDAYS	Deterministic	I3	1
18	AMONIQ	Deterministic	11F7.0	1
19	PCOST	Stochastic	11F4.3	One for each size range
20	ROUTE	Design	See main program	12 x NROUTE
21	PUBLIC	Stochastic	16F5.4/ 9F5.4	8
22	IDC, TOWER1 - TOWER5, ITC, IXCORD, IYCORD	Design	I2, 5A4, I2, I3, I3	NTOWER
23	RING	Design, Stochastic	F2.0, F1.0, F2.0, F4.3	20 x NTOWER
24	PFDIST	Stochastic	4F5.4	No. of months x No. of districts
25	MONTH, MCODE, IDAY, PS1 - PS4, PB1 - PB5	Deterministic, Stochastic	A4, I2, I2, 9F4.3	NDAYS
26	WHERE	Stochastic	See main program	No. of districts
27	PCDIST	Stochastic	10F5.4	No. of months x No. of districts
28	SPOT	Deterministic	6F8.5	No. of subdivisions
29	PTIME	Stochastic	10F5.4/10F5.4/10F5.4	3 x No. of cause categories
30	BTAB1	Deterministic	5I1	4
31	BTAB2	Deterministic	5I1	4
32	VIS	Stochastic	6F3.2	4
33	SPREAD	Deterministic	24F3.1	No. of months x No. of fuel categories
34	PFIRE	Stochastic	See main program	16

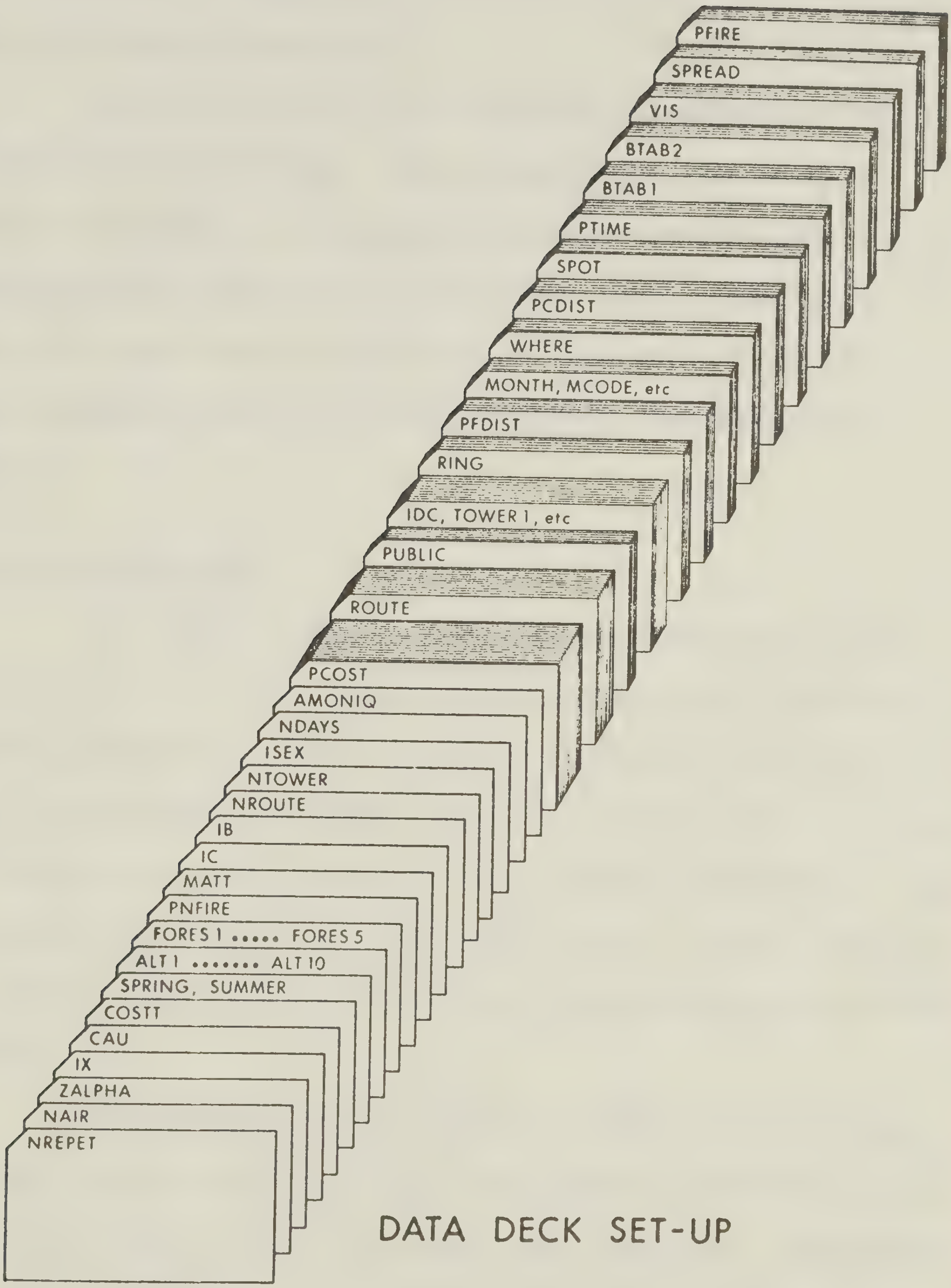

PFIRE
SPREAD
VIS
BTAB2
BTAB1
PTIME
SPOT
PCDIST
WHERE
MONTH, MCODE, etc
PFDIST
RING
IDC, TOWER 1, etc
PUBLIC
ROUTE
PCOST
AMONIQ
NDAYS
ISEX
NTOWER
NROUTE
IB
IC
MATT
PNFIRE
FORES 1 ..... FORES 5
ALT 1 .... ALT 10
SPRING, SUMMER
COSTT
CAU
IX
ZALPHA
NAIR
NREPET
DATA DECK SET-UP

FIGURE A-1

detection system. Examples of the values each of the variables takes on is shown in Appendix D.

An explanation of how the data is accumulated and key punched on IBM cards follows. Before reading the procedure for setting up the data for a variable, the reader should acquaint himself with the definition of the variable found in Appendix C, examine the input format found in either Table A-1 or the main program listing in Appendix B, and examine the data listing in Appendix D.

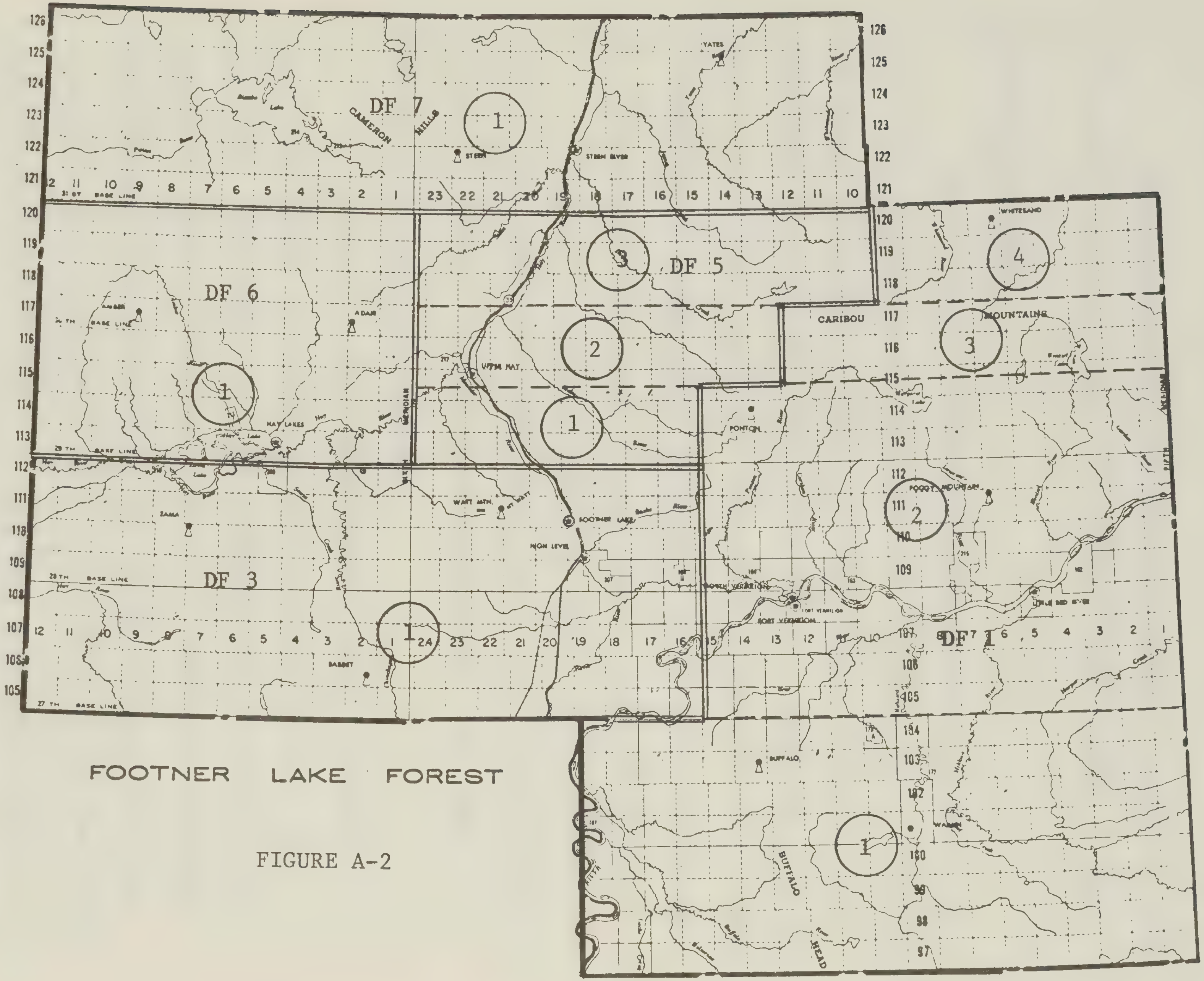
Deterministic Variables

The values of the deterministic variables are usually derived from two sources. One, they are heuristically evaluated by examining the system or two, they can be calculated from other variables evident within the system. Most of the deterministic variables in this model are of the heuristic nature and an examination of their definitions will explain the values they take on. However, some of the remaining deterministic variables are complex and require further explanation.

The variables CAU and AMONIQ are identical. The values for these vectors were calculated by averaging the suppression costs for all the fires in each of the cost range categories. For example, the average suppression cost of the fires falling within the $501 to $1,000 range was $742 for the Footner Forest.

The values for the matrix SPOT are determined by dividing the forest map up into ranger districts then dividing the ranger districts up into rectangular areas. This makes it possible to allow for irregular shaped ranger districts. The data for each rectangle is recorded on one card. This portion of the program is unique for each forest and will have to be modified for forests other than Footner. Figure A-2 shows how the Footner Forest was subdivided into rectangles. The rectangular areas are ordered according to ranger districts. The first four cards in this instance are for the 4 rectangles composing of DF1, the next card is for the rectangle describing DF3, and so on until all the rectangles are described. The data card records the values for six parameters describing the rectangle. The first eight columns display the reciprocal of the length of the Y side of the rectangle. Columns 9 - 16 are reserved for the reciprocal of the X length of the rectangle. Columns 17 - 24 and 25 - 32 are reserved for the length of the Y side and X side of the rectangle in miles respectively. Columns 33 - 40 and 41 - 48 are reserved for the Y and X coordinates of the southwest corner point of the rectangle.

The tables BTAB1 and BTAB2 are taken directly from the Alberta Forestry Brochure relating spread and build up indices to fire hazard. The numbers 1 to 5 replace the low, moderate, high, very high, and extreme hazard categories. BTAB1 is a spring and summer table and BTAB2 is a fall table. Examples of these two tables are shown in Figures 4-2 and 4-3.



FOOTNER LAKE FOREST

FIGURE A-2

The SPREAD matrix is described in Chapter 4 since it forms the basis of the growth model. The SPREAD table is shown in Figure 4-6.

Stochastic Variables

The stochastic variables are probabilistic in nature and determined by examining the frequency distributions found in historical fire data. The random variable is divided into several categories each taking on a different range of values. The number of times the value of the variable falls into each of the categories (the frequency distribution) is summed and a probability mass function determined. The probability of each range is calculated in the usual manner.

The first stochastic variable listed is called PNFIRE. This variable takes on a single value. This value is calculated by dividing the number of fires that have occurred by the number of days over which they have occurred.

The variable PCOST is designed by cross tabulating the eleven suppression cost ranges with the fifteen discovery size categories. The results are the frequency distributions of fire suppression costs for each size class. The cumulative probability mass function can then be derived and the Monte Carlo method used to determine the suppression cost of each fire once the size at discovery has been established. It should be noted here that the cost ranges are replaced with an average cost for each range. The data set CAU describes these average values.

The variable PUBLIC describes a time distribution for the public detection system. The values used to build the probability mass function for this variable are generated by cross tabulating the 25 time categories for each day with the 4 fuel categories.

PFDIST values of the probability mass function are determined by a three way cross tabulation. The fuel types are tabulated with the ranger districts holding the months constant. For example, in Footner, May will have five frequency distributions of fuels. One for each ranger district.

The stochastic portion of the MONTH, MCODE, etc., set up deck is PS1 to 4 and PB1 to 5. The values for these probability mass functions are determined from cross tabulations of each day in the fire season with the 4 ranges of Spread index and the 5 ranges of the Buildup index.

The probability mass function is determined for WHERE by cross tabulating the months with ranger districts. The frequencies of fires for each district in each month can then be determined. The probability mass function for PCDIST is determined by a three way cross tabulation. The tabulation of district with each fire cause holding the month constant produces the required frequency distributions. PTIME is determined by cross tabulating the 25 time categories with the 10 cause categories. A frequency distribution of time is established for each of the 10 cause classifications.

VIS is determined by cross tabulating the 4 Spread index categories with the 6 visibility categories. The frequency distribution for the visibility categories is determined for each of the Spread index categories.

PFIRE frequencies are determined by a 3 way cross tabulation of day with cause and holding the month constant. This will give a frequency distribution of the number of fires occurring on each day of the fire season.

Design Variables

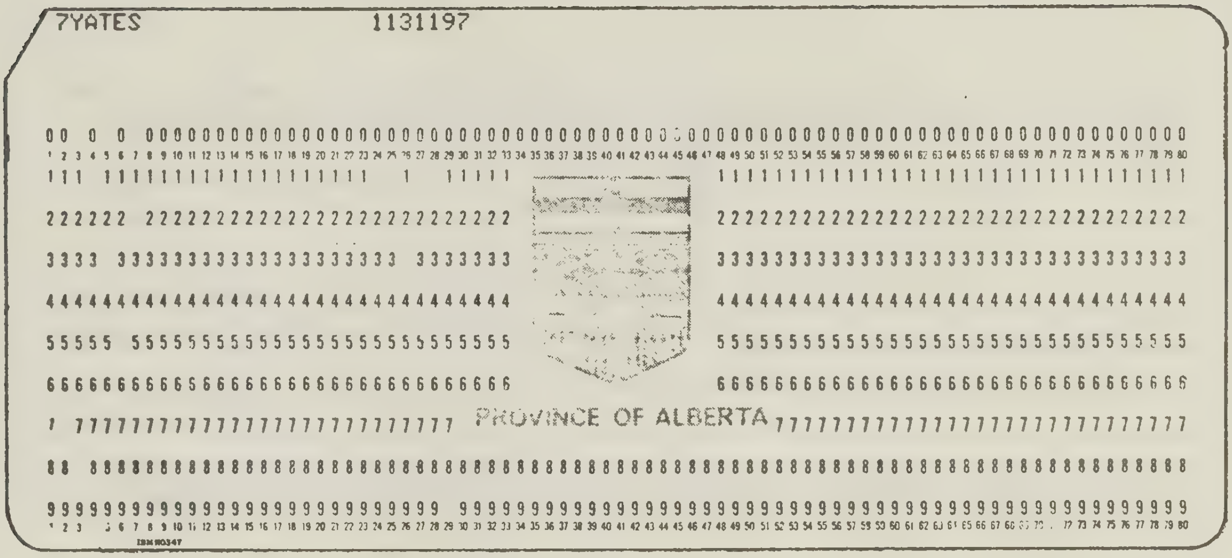
The design variables in the model are towers and air routes. The tower data is contained on two different sets of cards, the first set of cards is labeled IDC, TOWER1, etc. . The second data set is labeled RING. The air route data set is labeled ROUTE. When modifying the design alternatives, either the tower data or air route data or both can be modified.

Tower Data

An example of an IDC, TOWER1, etc., card is shown in Figure A-3. The tower data is recorded in the following manner. The first two columns are reserved for the ranger district number. Columns 3 to 22 inclusive are reserved for the tower name. Columns 23 and 24 are reserved for the tower number. Columns 25 to 27 inclusive are reserved for the tower's X coordinate and columns 28 to 30 are for the Y coordinate.

FIGURE A-3

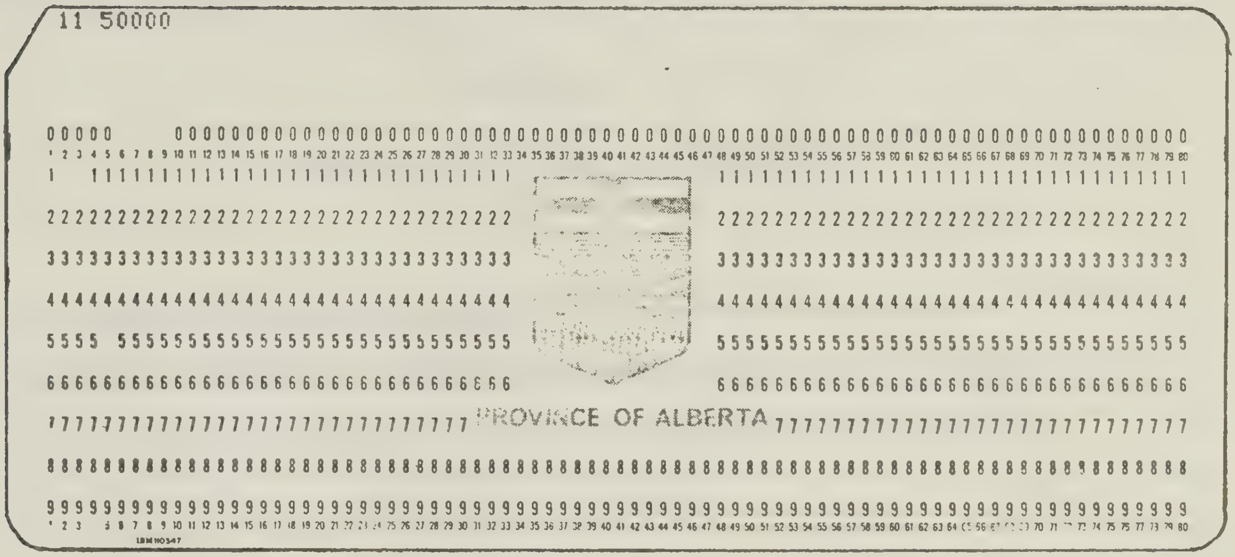
An Example of the Set Up Deck IDC, TOWER1, etc.



Corresponding to this first set of data is a second set of data called RING. An example of a RING card is shown in Figure A-4. This is the blind area data for each tower in the first set. The blind area data must be in the same order as the tower data or else the blind area data will be applied to the wrong tower. Each tower has 20 cards describing its blind area. A tower has 4 quadrants associated with it and each quadrant has 5 concentric quarter circles at 5 mile intervals. (See Figure 1-3). One data card contains information on a sector of each quadrant. Columns 1 and 2 are reserved for the quadrant number; column 3 for the RING number; columns 4 and 5 for the mileage of the RING from the tower; and

FIGURE A-4

An Example of the Set Up Deck RING



columns 6 to 9 inclusive for the probability of not being able to see the fire. This probability is the blind area in the sector divided by total area in the sector. The RING portion of the tower design is stochastic.

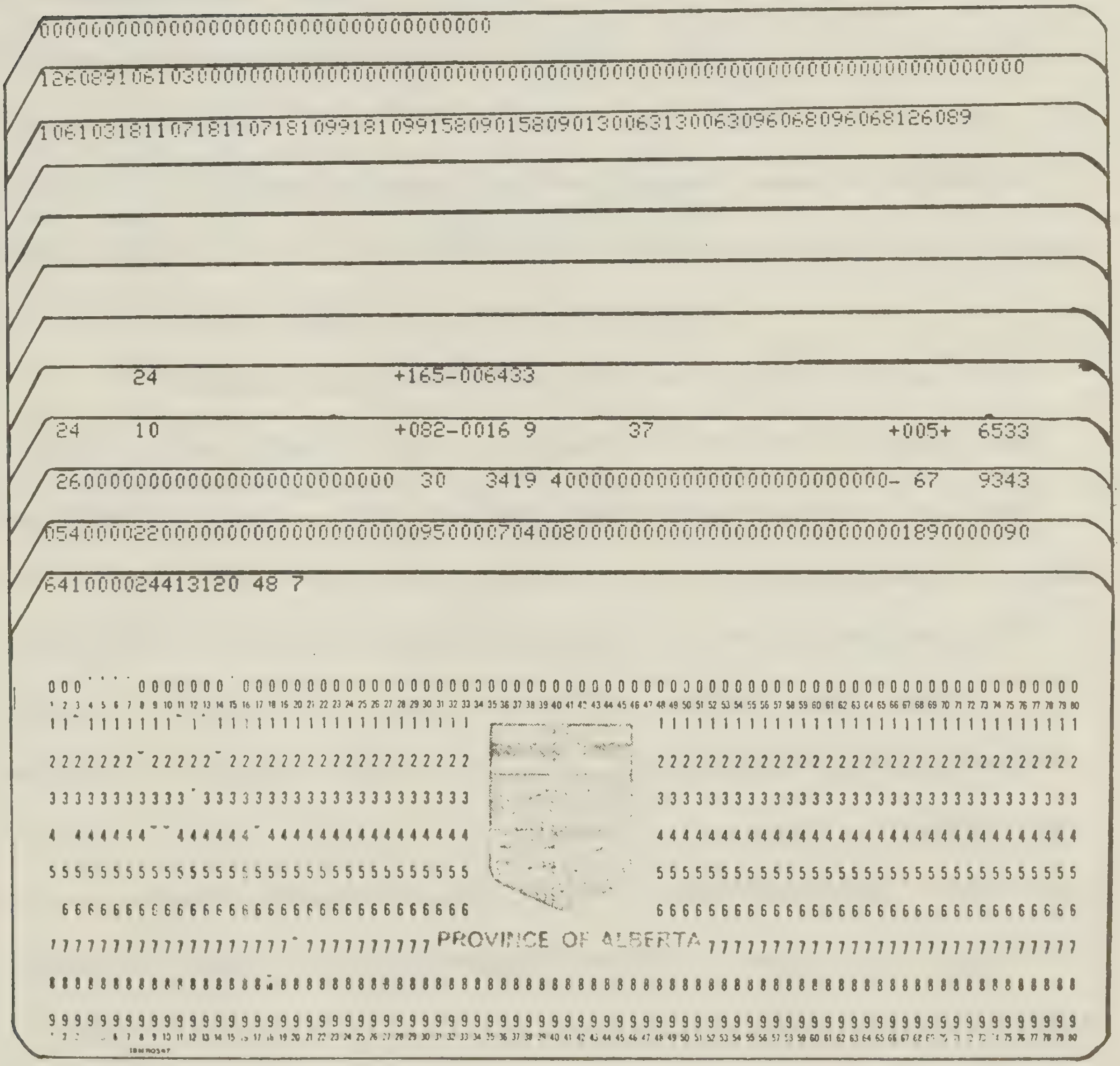
It should be noted that a tower called DUMMY had been added to the tower code names (See Appendix E). The purpose of the DUMMY tower was to allow the system to have a design alternative of zero towers. Since there must always be at least 1 tower to allow the program to run, a DUMMY tower located well outside the forest and having fictional RING data serves the purpose.

Air Route Data

The air route data is located in the set up deck called ROUTE. An example of the set up deck is shown in Figure A-5.

FIGURE A-5

An Example of the Set Up Deck ROUTE

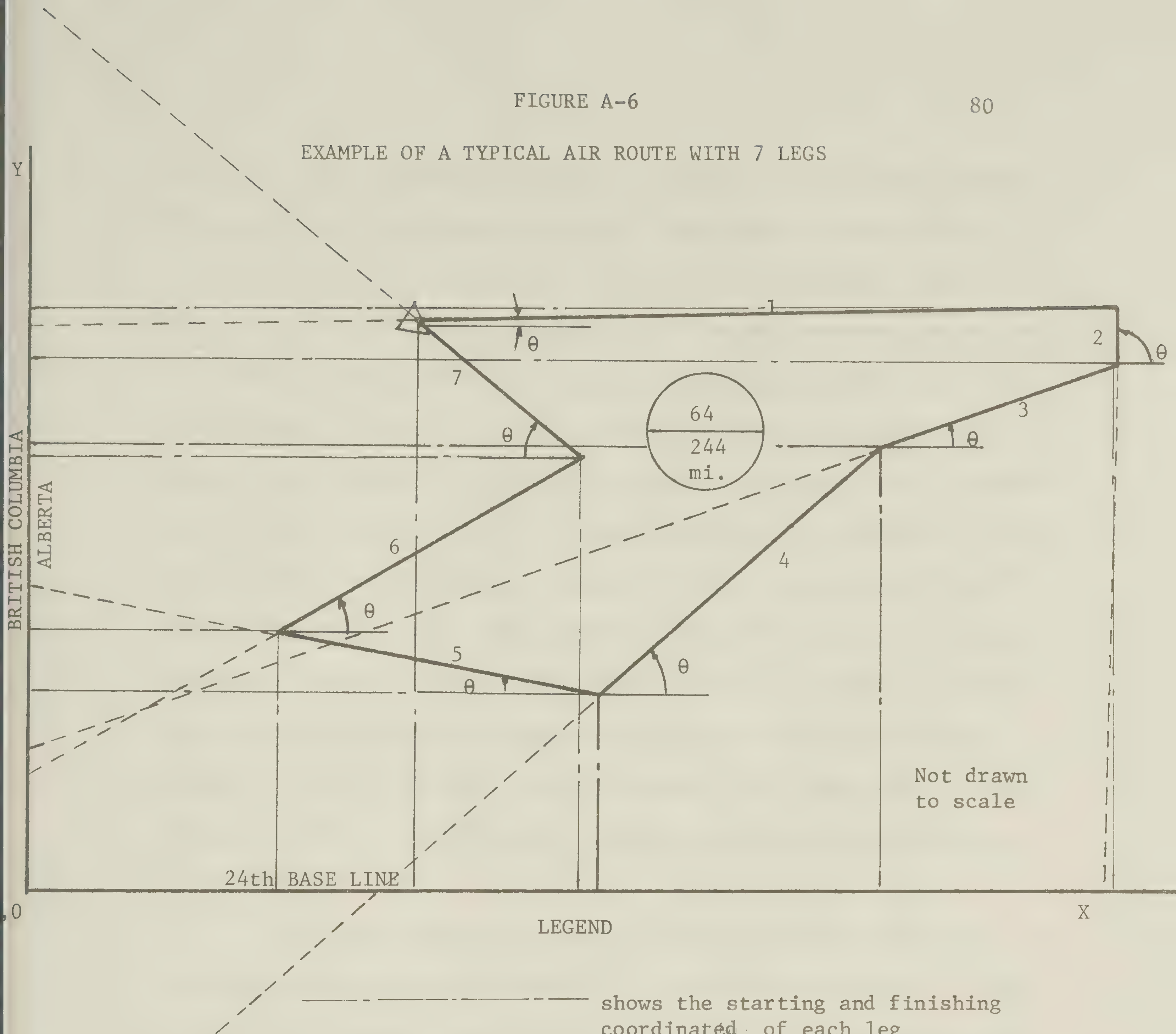


Each air route uses twelve data cards to describe it. The first card gives a general description of the air route. Columns 1 and 2 are reserved for the ROUTE number, columns 3 to 7 inclusive represent the 5 months May to September. If the ROUTE is to be flown in any of the 5 months, a 1 is punched in the corresponding column. If the ROUTE is not to be used during a month, a 0 is punched in the corresponding column. Columns 8 to 10 inclusive are reserved for the total mileage of the air route; columns 11 and 12 for the 24 hour clock time the aircraft begins the flight; i.e. 1 p.m. = 13. Columns 13 to 15 are reserved for the aircraft speed in miles per hour; columns 16 to 18 for the cost in dollars per hour; and columns 19 and 20 for the number of legs on the ROUTE.

The next eight cards describe the air route shape and location. (See Figure A-6). The legs are counted clockwise from the starting point. Each time the ROUTE changes direction, a new leg starts. The program will accept up to 15 legs per ROUTE. Blank cards must be used to fill in the data for non-existing legs. For example, if there are 7 legs on a ROUTE, 4 blank cards will be required to complete the 8 leg cards. There are 38 columns used to describe an air route leg. The program is designed to describe the path of a ROUTE through a maximum of 9 ranger districts. There are 3 columns set aside for each ranger district to record the length of the leg in that district. If the leg does not pass through a ranger district, the columns are left blank. The first 27 columns are used

FIGURE A-6

EXAMPLE OF A TYPICAL AIR ROUTE WITH 7 LEGS



LEGEND

——— - ———— - —— shows the starting and finishing coordinated of each leg

— — — — — — — — shows where the Y intercept is measured for each leg

Notice that for leg 2 because it is vertical, the intercept measured is the "X" intercept

If θ = 90, measure the X intercept, and the slope columns are left blank.

If θ = 0, measure the Y intercept and the slope columns are left blank.

If θ = 0-90, measure the Y intercept and the slope is measured as tan θ.

then, to record the length in miles of the leg in each ranger district. Columns 28 to 31 are reserved for the Y intercept (X intercept) of the leg. This is the distance in miles from the reference origin for the entire forest to where the leg, when extended, crosses the vertical (horizontal) axis. Which intercept to use depends on the value of θ, see the note on Figure A-6. The reference origin is located so the forest being tested is in the first quadrant (see Figure A-6). Column number 28 is reserved for a + or - sign depending on whether the intercept is positive or negative. Columns 32 to 36 are reserved for the slope of the leg. Again, this number is preceded by a + or - sign in column 32. Columns 37 and 38 are reserved for θ, the smallest angle the leg forms with the horizontal. The value of θ is recorded in degrees. Data for the next leg is repeated in this same order between columns 39 to 76. In this manner, data for each leg is recorded up to leg 15.

The last three cards in the 12 card ROUTE deck are used to store data on the limitations of the air route previously described on the first 9 cards. Since the air route legs are described in terms of straight lines, of specific intercepts and angles, there must be some constraints placed on the boundaries of the routes, otherwise the leg will be viewed by the computer as being of infinite length.

The last three cards, 72 columns on each of the first two and 36 on the last, are used to describe the X and Y limits for each leg. The first 12 columns are reserved for the starting X coordinate,

starting Y coordinate, finishing X coordinate and finishing Y coordinate of the first leg. The next 12 columns for the second leg and so on until data for the 15 legs is recorded. For non-existing legs the data card is again left blank.

The air routes can be modified by changing the time the flight originates, the physical description of the legs or by adding new routes. The same air routes can be reflown later in the day by changing the air route number and the starting time and treating it as a completely new route. When the same air route is flown more than once, the descriptive statistics calculated showing the effectiveness of the air routes in the print out routine will be wrong, unless the variable NREPET is changed. The present program limits the designer to flying all the routes at the same frequency. The routes must be flown either all once or all twice etc.

APPENDIX B

A LISTING OF THE MAIN PROGRAM

```
$SIGNON GAVM 'LIST'
ON AT  23:44.54 CN 04-10-72  LAST ON AT  23:12.43
$LIST *SOURCE*
      C              FOBTRAN  IV   G       MAIN  PROGRAM

      C      FOCTNEF FOREST      FOREST FIRE DETECTION SYSTEM DESIGN MODEL

      C      THIS IS A PROTOTYPE DESIGN MODEL FOR THE ENTIRE ALBERTA FOREST SYSTEM


      C      THE DIMENSION STATEMENTS LISTED BELOW  ARE FOR THE ENTIRE PROGRAM

             INTEGER TTTIME
             INTEGER TOWER,FUEL
             INTEGER SPRING, SUMMER
             INTEGER SPRDEX,BUPDEX,SCOUNT,DIST,CAUSE,TIME
            1,BTAB1(4,5),BTAB2(4,5),BURNDX,HORIZN
             DIMENSION ATOWER(30),PNFD(30),AROUTE(15),PTFD(30),PSNFA(
            115),PTFDA(15),AIFUEL(4),PGREAT(4)
             DIMENSION X(500)
             DIMENSION AMAY(15),REST(15)
             DIMENSION GT$(11)
             DIMENSION BROUTE(15), PSNFA2(15),PTFDA2(15)
             DIMENSION PCOST(15,11),AMONIQ(11)
             DIMENSION CRANGE(11),PRANGE(11),CT$(11),CAU(11)
             DIMENSION ROUTE(15,251),IBOYD(15),PUBLIC(4,25)
             DIMENSION RING(600,4)
             DIMENSION IDC(30),TOWER1(30),TOWER2(30),TOWER3(30),TOWER4(30),
            1TOWER5(30),IIC(30),IYCORD(30),IXCORD(30)
             DIMENSION PFDIST(25,4)
             DIMENSION DRANGE(11)
             DIMENSION RCS(10),PRCS(10)
             DIMENSION RSIZE(15),PSIZE(15),PRSIZE(15)
             DIMENSION RV(6),PRV(6)
             DIMENSION MONTH(153),IDAY(153),MCODE(153),PS1(153),PS2(153),PS3(15
            13),PS4(153),PB1(153),PB2(153),PB3(153),PB4(153),PB5(153),WHERE(5,5
            1)
             DIMENSION SPOT(10,6),MCOORD(2)
             DIMENSION PCDIST(25,10),PTIME(10,25),
            1VIS(4,6),FIDAYS(153),PFIRE(153),SPREAD(4,5,24)
            1,EDIST(5,10),XN(24),XNORML(24)
             COMMON IX,IY,YFL


      C      THIS SECTION OF THE PROGRAM READS IN ALL THE DATA REQUIRED TO DRIVE
      C      THE SIMULATION MODEL

      C      NREPET=1,2,OR 3 IF AIRCRAFT FLY ONCE,TWICE,OR THREE TIMES
             READ(5,4441)NREPET
        4441 FORMAT(I1)
      C      NAIR IS EQUAL TO THE NUMBER OF AIRCRAFT REQUIRED
             READ(5,6201)NAIR
        6201 FORMAT(I2)
      C      ZALPHA IS THE PERCENTILE OF THE NORMAL DISTRIBUTION WHICH LEAVES
      C      ALPHA/2 PERCENT PROBABILITY IN EACH TAIL
             READ(5,3501)ZALPHA
        3501 FORMAT(F5.4)
      C      IX IS THE SEED FOR THE RANDOM NUMBER GENERATOR
```

```
C              FORTRAN  IV   G       MAIN  PROGRAM


      READ(5,3500) IX
 3500 FORMAT(I9)
      IIX = IX
C     CAU IS A VECTOR OF 11 AVERAGE COSTS
      READ(5,2034)  (CAU(J),J=1,11)
 2034 FORMAT(11F6.0)
C     COSTT IS THE SEASONAL COST PER TOWER
      READ(5,2017)COSTT
 2017 FORMAT(F10.0)
C     SPRING,SUMMER IS THE NUMBER OF AIR ROUTES OPERATING IN SPRING AND SUMMER
      READ(5,2006)SPRING, SUMMER
 2006 FORMAT(2I2)
C     ALT1 TO ALT10 IS THE DESIGN ALTERNATIVE FOR THIS RUN
      READ(5,2003)ALT1,ALT2,ALT3,ALT4,ALT5,ALT6,ALT7,ALT8,ALT9,ALT10
 2003 FORMAT(10A4)
C     FORES1 TO FORES5 IS THE NAME OF THE FOREST
      READ(5,2001)  FORES1,FORES2,FORES3,FORES4,FORES5
 2001 FORMAT(5A4)
C     PNFIRE IS THE PROBABILITY OF HAVING A FIRE FOR EACH DAY IN THE SEASON
      READ(5,3017) PNFIRE
 3017 FORMAT(F10.5)
C     READ THE FLYING CODE CRITERIA. IF MATT =0,CHECK WEATHER AND CAUSE. IF
C     MATT=1,ALWAYS FLY. IF MATT=2,NEVER FLY.
      READ(5,745) MATT
C     READ THE CAUSE REQUIRED TO INITIATE AIRCRAFT
      READ(5,745) IC
  745 FORMAT(I2)
C     READ THE MINIMUM BURNING INDEX REQUIRED TO INITIATE AIRCRAFT
      READ(5,745) IB
C     READ THE NUMBER OF AIRCRAFT ROUTES BEING USED.
      READ(5,748) NROUTE
  748 FORMAT(I2)
C     READ THE NUMBER OF TOWERS OPERATING IN THE SYSTEM
      READ(5,797) NTOWER
  797 FORMAT(I2)
      KEY= 20 * NTOWER
C     READ THE NUMBER OF FIRE SEASONS BEING CONSIDERED
      READ(5,648) ISEX
  648 FORMAT(I4)
C     READ THE NUMBER OF DAYS IN A FIRE SEASON.
      READ(5,1) NDAYS
    1 FORMAT(I3)
C     AMONIQ IS A VECTOR OF AVERAGE SUPPRESSION COSTS
      READ(5,1405) (AMONIQ(J),J=1,11)
 1405 FORMAT(11F7.0)
C     PCOST IS A TABLE OF FIRE SIZE AT DISCOVERY VS. AVERAGE SUPPRESSION COSTS
      READ(5,1400)  ((PCOST(I,J),J=1,11),I=1,15)
 1400 FORMAT  (11F4.3)
C     ROUTE IS A TABLE OF DATA  DISCRIBING EACH AIR ROUTE
      READ(5,720)  ((ROUTE(I,J),J=1,251),I=1,NROUTE)
  720 FORMAT(F2.0,5F1.0,F3.0,F2.0,F3.0,F3.0,F2.0/
     19F3.0,F4.0,F5.2,F2.0,9F3.0,F4.0,F5.2,F2.0/
```

```
C               FORTRAN  IV   G        MAIN  PROGRAM


         19F3.0,F4.0,F5.2,F2.0,9F3.0,F4.0,F5.2,F2.0/
         19F3.0,F4.0,F5.2,F2.0,9F3.0,F4.0,F5.2,F2.0/
         19F3.0,F4.0,F5.2,F2.0,9F3.0,F4.0,F5.2,F2.0/
         19F3.0,F4.0,F5.2,F2.0,9F3.0,F4.0,F5.2,F2.0/
         19F3.0,F4.0,F5.2,F2.0,9F3.0,F4.0,F5.2,F2.0/
         19F3.0,F4.0,F5.2,F2.0,9F3.0,F4.0,F5.2,F2.0/
         19F3.0,F4.0,F5.2,F2.0/24F3.0/24F3.0/12F3.0)
C     PUBLIC IS A TABLE OF CUMULATIVE PROBABILITIES FOR BURNING TIME
C     IF THE FIRE IS DISCOVERED BY THE PUBLIC
      READ(5,737) ((PUBLIC(I,J),J=1,25),I=1,4)
  737 FORMAT(16F5.4/9F5.4)
C      READ THE LOCATION NAME AND COORDINATES OF EACH RELEVANT TOWER
      DO 798 J = 1,NTOWER
      READ(5,799) IDC(J),TOWER1(J),TOWER2(J),TOWER3(J),TOWER4(J),TOWER5(
     1J),ITC(J),IXCORD(J),IYCORD(J)
  799 FORMAT(I2,5A4,I2,I3,I3)
  798 CONTINUE
C     READ THE BLIND AREA DATA FOR EACH TOWER IN THE SYSTEM
       READ(5,795) ((RING(I,J),J=1,4),I=1,KEY)
  795 FORMAT(F2.0,F1.0,F2.0,F4.3)
C     READ THE CUMULATIVE PROBABILITY DATA FOR THE DIFFERENT FUELS
C     GIVEN THE DISTRICT AND MONTH OF THE FIRE
      READ(5,300) ((PFDIST(I,J),J=1,4),I=1,25)
  300 FORMAT(4F5.4)
C     READ FOR EACH DAY IN THE MONTH, THE NAME OF THE MONTH,THE CODE FOR
C     THE MONTH,AND THE CUMULATIVE PROBABILITIES OF BUILDUP INDEX
C     AND SPREAD INDEX FOR EACH DAY
      READ(5,2)  (MONTH(J),MCODE(J),IDAY(J),PS1(J), PS2(J),PS3(J),PS4(J),
     1PB1(J),PB2(J),PB3(J),PB4(J), PB5(J),J=1,153)
    2 FORMAT(A4,I2,I2,9F4.3)
C     READ THE MONTHLY CODE AND THE CUMULATIVE PROBABILITIES FOR FIRES
C     OCCURRING IN ANY GIVEN DISTRICT
      READ(5,4) ((WHERE(I,J),J=1,5),I=1,5)
    4 FORMAT(2X,5F5.4/2X,5F5.4/2X,5F5.4/2X,5F5.4/2X,5F5.4)
C     READ THE CUMULATIVE PROBABILITIES FOR A FIRE BEING CAUSED IN A
C     PARTICULAR DISTRICT BY A GIVEN EVENT
      READ(5,5)   ((PCDIST(I,J),J=1,10),I=1,25)
    5 FORMAT(10F5.4)
C     READ THE MAP DATA NECESSARY TO SPOT THE FIRES
      READ(5,199) ((SPOT(I,J),J=1,6),I=1,10)
  199 FORMAT(6F8.5)
C     READ DATA FOR CAUSE VS CUMU'ATIVE PROBABILITY OF TIME OF DAY OF FIRE START
      READ(5,10) ((PTIME(I,J),J= 1,25),I=1,10)
   10 FORMAT(10F5.4/10F5.4/5F5.4)
C     READ VALUES OF BURNING INDEX IN TERMS OF BUILDUP INDEX AND SPREAD
C     INDEX    BTAB1 = SPRING AND SUMMER BTAB2 = FALL
      READ(5,23) ((BTAB1(I,J),J=1,5),I=1,4)
      READ(5,23) ((BTAB2(I,J),J=1,5),I=1,4)
   23 FORMAT(5I1)
C     READ CUMULATIVE PROBABILITY FOR VISIBILITY IN MILES VS SPREAD INDEX
      READ(5,24) ((VIS(I,J),J=1,6),I=1,4)
   24 FORMAT(6F3.2)
```

```
C               FORTRAN  IV   G        MAIN  PROGRAM


C       READ VALUES FOR RATE OF FIRE SPREAD WHERE I INDEX REFERS TO FUEL TYPE
C       J INDEX REFERS TO THE BURNING INDEX AND THE K INDEX REFERS TO TIME OF DAY
        DO 33 I = 1,4
        DO 34 J = 1,5
        READ(5,32)  (SPREAD(I,J,K),K=1,24)
     32 FORMAT(24F3.1)
     34 CONTINUE
     33 CONTINUE
        DO 672 I = 1,4
        DO 671 J = 1,5
    671 CONTINUE
    672 CONTINUE
C       READ THE CUMULATIVE PROBABILITIES FOR A FIRE OCCURRING ON ANY GIVEN DAY
C       DURING THE 153 DAY FIRE SEASON
        READ(5,30)  (PFIRE(J),J=1,153)
     30 FORMAT(10F7.6/10F7.6/10F7.6/10F7.6/10F7.6/10F7.6/10F7.6/10F7.6/
       110F7.6/10F7.6/10F7.6/10F7.6/10F7.6/10F7.6/10F7.6/3F7.6)


C       THIS SECTION OF THE PROGRAM ZERO'S ALL THE REQUIRED SEASONAL COUNTERS

        TAMAY=0.
        TTACRE=0.
        TREST=0.
        VAR=0.
        XBAR=0.
        SIGMA=0.
        D=0.
        TPTFD2=0.
        TPSNF2=0.
        TPAD=0.
        TSNFD=0.
        TPNFD=0.
        TPTFD = 0.
        TSNFA=0.
        TPSNFA=0.
        TPTFDA=0.
        SNFF=0.
        TOTALG=0.
        GREAT=0.
        DAY$A = 0.
        RANGE = 0.
        SUMPR = 0.
        ST$ = 0.
        SRSIZE = 0.
        SPSIZE = 0.
        SRCS = 0.
        SPRCS = 0.
        SRV = 0.
        SPRV = 0.
        TACRES = 0.
        DO 4013 J=1,4
```

```
C               FORTRAN  IV   G        MAIN  PROGRAM


          AIFUEL(J)=0.
          PGFEAT(J)=0.
 4013 CONTINUE
          DO 4007 J=1,NROUTE
          BFCUTE(J)=0.
          AFCUTE(J)=0.
          PSNFA(J)=0.
          PTFDA(J)=0.
          PSNFA2(J)=0.
          PTFDA2(J)=0.
 4007 CONTINUE
          DO 4000 J=1,NTOWER
          ATOWER(J)=0.
          PNFD(J)=0.
          PTFD(J)=0.
 4000 CONTINUE
          DO 2028 J = 1,11
          GT$(J) = 0.
          CT$(J) = 0.
          CRANGE(J) = 0.
          PRANGE(J) = 0.
 2028 CONTINUE
          DO 2053 I = 1,15
          AMAY(I) =0.
          REST(I) = 0.
          RSIZE(I) = 0.
          PSIZE(I) = 0.
 2053 CONTINUE
          DO 2057 J = 1,10
          RCS(J) = 0.
          PRCS(J) = 0.
 2057 CONTINUE
          DO 2061 J = 1,10
          RV(J) = 0.
          PRV(J) = 0.
 2061 CONTINUE


C         8888 IS THE RANGE FOR THE SEASONAL CALCULATIONS

          DO 8888 MMMM = 1,ISEX
          DO 7650 J=1,11
          DRANGE(J)=0.
 7650 CONTINUE
          BT$=0.
          XXEAP=0.
          VVAR=0.
          AA$=0.
          JSEX = ISEX
          JSEX=MMMM
          NDEX = MMMM
          MCOUNT = 0
```

```
C              FORTRAN  IV   G       MAIN  PROGRAM


      FIRE = 0.


C     THIS SECTION CALCULATES THE NUMBER OF FIRES IN THE SEASON

      DO 28 J = 1,153
C     GREG IS THE NAME OF THE RANDOM NUMBER GENERATOR
      CALL GREG
      IF(YFL .LE. PNFIRE)FIRE = FIRE + 1.
   28 CONTINUE
C     THIE SECTION ASSIGNS THE FIRES FOR THIS SEASON TO A PARTICULAR DAY

      IFIRE = FIRE
      DO 29 J = 1,153
   29 FIDAYS(J) = 0.
      DO 31 J = 1,IFIRE
      CALL GREG
      INDEX = 0
      DO 66 I = 1,153
      INDEX = I
      IF(I .EQ.1)GO TO 65
      IF(I.EQ.153)GO TO 84
      IF(YFL.GT.PFIRE(I-1).AND.YFL.LE.PFIRE(I  ))GO TO 67
      GO TO 66
   84 IF(YFL.GT.PFIRE(I-1))GO TO 67
   65 IF(YFL.LE.PFIRE(I))GO TO 67
   66 CONTINUE
   67 FIDAYS(INDEX) = FIDAYS(INDEX) + 1.
   31 CONTINUE


C     STATEMENT 9999 IS THE RANGE FOR THE MONTHLY CALULATION BY DAY

      XKCUNT=0.
      DO 9999 KKKK = 1,NDAYS
      IBCB = 0
      KKK = KKKK
      IFIDA = FIDAYS(KKKK)
      IF(IFIDA .GT.0)GO TO 649
      IF(KKK.EQ.1.OR.KKK.EQ.32.OR.KKK.EQ.62.OR.KKK.EQ.93.OR.KKK.EQ.124)
     1GO TO 3
      GO TO 2018


C     THIS SECTION CALCULATES THE SPREAD INDEX FOR THE DAY

  649 CALL GREG
      IF(YFL.LE.PS1(KKKK))SPRDEX = 1
      IF(YFL.GT.PS1(KKKK).AND.YFL.LE.PS2(KKKK))SPRDEX = 2
      IF(YFL.GT.PS2(KKKK).AND.YFL.LE.PS3(KKKK))SPRDEX = 3
      IF(YFL.GT.PS3(KKKK).AND.YFL.LE.PS4(KKKK))SPRDEX = 4
```

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C              FORTRAN  IV   G       MAIN  PROGRAM


C     THIS SECTION CALCULATES THE BUILD UP INDEX FOR THE DAY

      IF(YFL.LE.PB1(KKKK))BUPDEX = 1
      IF(YFL.GT.PB1(KKKK).AND.YFL.LE.PB2(KKKK))BUPDEX = 2
      IF(YFL.GT.PB2(KKKK).AND.YFL.LE.PB3(KKKK))BUPDEX = 3
      IF(YFL.GT.PB3(KKKK).AND.YFL.LE.PB4(KKKK))BUPDEX = 4
      IF(YFL.GT.PB4(KKKK).AND.YFL.LE.PB5(KKKK))BUPDEX = 5
      IF(IFCB .EQ. 1)GO TO 651


C     THIS IS A CHECK TO SEE IF THERE IS A FIRE ON THIS DAY

      IF(KKK.EQ.1.OR.KKK.EQ.32.OR.KKK.EQ.62.OR.KKK.EQ.93.OR.KKK.EQ.124)
     1GO TO 3
      GO TO 6
    3 MCOUNT = MCOUNT + 1
      MDIANE = 5 * (MCOUNT - 1)
      IF(IFIDA .EQ. 0)GO TO 2018


C     THIS SECTION LOCATES THE DISTRICT THE FIRE OCCURS IN

    6 XKOUNT = XKOUNT + 1.
      CALL GREG
      IF(YFL.LE.WHERE(MCOUNT,1))DIST = 1
      IF(YFL.GT.WHERE(MCOUNT,1).AND.YFL.LE.WHERE(MCOUNT,2))DIST = 3
      IF(YFL.GT.WHERE(MCOUNT,2).AND.YFL.LE.WHERE(MCOUNT,3))DIST = 5
      IF(YFL.GT.WHERE(MCOUNT,3).AND.YFL.LE.WHERE(MCOUNT,4))DIST = 6
      IF(YFL.GT.WHERE(MCOUNT,4).AND.YFL.LE.WHERE(MCOUNT,5))DIST = 7
      IF(DIST .EQ. 1)IDIST = 1
      IF(DIST .EQ. 3)IDIST = 2
      IF(DIST .EQ. 5)IDIST = 3
      IF(DIST .EQ. 6)IDIST = 4
      IF(DIST .EQ. 7)IDIST = 5
      MARK = MDIANE + IDIST


C     THIS SECTION LOCATES THE X AND Y COORDINATES FOR THE FIRE

      IF (IDIST-1) 198,198,197
  198 CALL GREG
      IF(YFL.GT.0..AND.YFL.LE..404)NROW=1
      IF(YFL.GT..404.AND.YFL.LE..835)NROW=2
      IF(YFL.GT..835.AND.YFL.LE..921)NROW=3
      IF(YFL.GT..921.AND.YFL.LE.1.)NROW=4
      GO TO 195
  197 IF (IDIST-3) 192,196,192
  196 CALL GREG
      IF(YFL.GT.0..AND.YFL.LE..242)NROW=6
      IF(YFL.GT..242.AND.YFL.LE..544)NROW=7
      IF(YFL.GT..544.AND.YFL.LE.1.0)NROW=8
      GO TO 195
```

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C              FORTRAN  IV   G        MAIN  PROGRAM

  192 IF(IDIST.EQ.2)NROW=5
      IF(IDIST.EQ.4)NROW=9
      IF(IDIST.EQ.5)NROW=10
  195 DO 130 KK=1,2
      MM=SECT(NROW,KK+2)
      CALL GREG
      DO 131 J=1,MM
      XJ=J
      INDEX=J
      CUMP1=XJ*SECT(NROW,KK)
      CUMP2=CUMP1-SECT(NROW,KK)
      IF(J.EQ.1)GO TO 127
      IF(YFL.GT.CUMP2.AND.YFL.LE.CUMP1)GO TO 128
      GO TO 131
  127 IF(YFL.GT.0..AND.YFL.LE.CUMP1)GO TO 128
  131 CONTINUE
  128 IF(INDEX.EQ.1)GO TO 129
      MCOORD(KK)=SPOT(NROW,KK+4)+INDEX
      GO TO 130
  129 MCOORD(KK)=SPOT(NROW,KK+4)
  130 CONTINUE

C     THIS SECTION CALCULATES THE CAUSE OF THE FIRE

      CALL GREG
      INDEX = 0
      DO 7 J = 1,10
      INDEX = J
      IF(J .EQ.  1)GO TO 8
      IF(J.EQ.10)GO TO 83
      IF(YFL.GT.PCDIST(MARK,J-1).AND.YFL.LE.PCDIST(MARK,J))GO TO 9
      GO TO 7
   83 IF(YFL.GT.PCDIST(MARK,J-1))GO TO 9
    8 IF(YFL.LE.PCDIST(MARK,J))GO TO 9
    7 CONTINUE
    9 CAUSE = INDEX
      BCS(INDEX) = BCS(INDEX) + 1.

C     THIS SECTION CALCULATES THE FUEL THE FIRE IS BURNING IN

      CALL GREG
      INDEX=0
      DO 302 J=1,4
      INDEX=J
      IF(J.EQ.1)GO TO 304
      IF(J.EQ.4)GO TO 305
      IF(YFL.GT.PFDIST(MARK,J-1).AND.YFL.LE.PFDIST(MARK,J))GO TO 306
      GO TO 302
  305 IF(YFL.GT.PFDIST(MARK,J-1))GO TO 306
  304 IF(YFL.LE.PFDIST(MARK,J))GO TO 306
```

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C              FORTRAN  IV   G        MAIN  PROGRAM


  302 CONTINUE
  306 FUEL=INDEX
      AIFUEL(INDEX)=AIFUEL(INDEX)+1.
C     THIS SECTION CALCULATES THE TIME OF DAY THE FIRE STARTS

      CALL GREG
      INDEX = 0
      DO 11 J =1,25
      INDEX = J
      IF(J.EQ.1)GO TO 12
      IF(J.EQ.25)GO TO 82
      IF(YFL.GT.PTIME(CAUSE,J-1).AND.YFL.LE.PTIME(CAUSE,J  ))GO TO 13
      GO TO 11
   82 IF(YFL.GT.PTIME(CAUSE,J-1))GO TO 13
   12 IF(YFL.LE.PTIME(CAUSE,J))GO TO 13
   11 CONTINUE
   13 TIME = INDEX


C     THIS SECTION REASIGNS TIMES FOR FIRES THAT HAD UNKNOWN STARTING TIMES

      IF(TIME .EQ. 25)GO TO 14
      GO TO 15
   14 SUM = 0.
      DO 16 J = 1,24
      SUM = SUM + PTIME(CAUSE,J)
   16 CONTINUE
      DO 17 J = 1,24
   17 XN(J) = PTIME(CAUSE,J)/SUM
      DO 18 J = 1,24
      IF(J.EQ.1)GO TO 19
      XNORML(J) = XN(J) + XNORML(J-1)
      GO TO 18
   19 XNORML(J) = XN(J)
   18 CONTINUE
      CALL GREG
      INDEX = 0
      DO 20 J = 1,24
      INDEX = J
      IF(J.EQ.1)GO TO 21
      IF(J.EQ.24)GO TO 81
      IF(YFL.GT.XNORML(J-1).AND.YFL.LE.XNORML(J  ))GO TO 22
      GO TO 20
   81 IF(YFL.GT.XNORML(J-1))GO TO 22
   21 IF(YFL.LE.XNORML(J))GO TO 22
   20 CONTINUE
   22 TIME = INDEX


C     THIS SECTION CALCULATES A BURNING INDEX USING THE SPREAD AND
C     BUILD UP INDEX TABLES
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C              FORTRAN  IV   G       MAIN  PROGRAM


   15 IF(XKOUNT-1.)651,651,1090
  651 IF(MCODE(KKKK).EQ.1.OR.MCODE(KKKK).EQ.2.OR.MCODE(KKKK).EQ.3)BURNDX
     1=BTAB1(SPRDEX,BUPDEX)
      IF(MCODE(KKKK).EQ.4.OR.MCODE(KKKK).EQ.5)BURNDX=BTAB2(SPRDEX,BUPDEX
     1)


C     THIS SECTION CALCULATES THE VISIBILITY FOR THE DAY

      CALL GREG
      INDEX = 0
      DO 25 J = 1,6
      INDEX = J
      IF(J.EQ. 1)GO TO 26
      IF(J.EQ.6)GO TO 80
      IF(YFL.GT.VIS(SPRDEX,J-1).AND.YFL.LE.VIS(SPRDEX,J  ))GO TO 27
      GO TO 25
   80 IF(YFL.GT.VIS(SPRDEX,J-1))GO TO 27
   26 IF(YFL.LE.VIS(SPRDEX,J))GO TO 27
   25 CONTINUE
   27 HORIZN = (INDEX * 5) - 5
      RV(INDEX) = RV(INDEX) + 1.
      IF(IBOB .EQ. 1)GO TO 2019


C     THIS SECTION DETERMINES WHETHER THE TOWERS ARE CLOSE ENOUGH TO SEE
C     THE FIRE

 1090 INK=1
 1000 DO 793 J = INK,NTOWER
      INDEX = J
      LENGTH=((IABS(MCOORD(2)-IXCORD(J)))**2+(IABS(MCOORD(1)-IYCORD(J)))
     1**2)**.5
      IF(LENGTH.LE.HORIZN)GO TO 792
      IF(J.EQ.NTOWER)GO TO 791
  793 CONTINUE
  792 TOWER = INDEX
      ITOWER=TOWER
      GO TO 790
  791 IBURNT=7777
      GO TO 750


C     IF THE TOWERS ARE CLOSE ENOUGH, THIS SECTION CHECKS THE BLIND AREA
C     OF THE TOWER TO VERIFY THAT THE FIRE CAN BE SEEN

  790 IF(MCOORD(2)-IXCORD(TOWER) .GE.0.AND.MCOORD(1)-IYCORD(TOWER).GE.0)
     1IQUAD=1
      IF(MCOORD(2)-IXCORD(TOWER).LE.0.AND.MCOORD(1)-IYCORD(TOWER).GE.0)I
     1QUAD = 2
      IF(MCOORD(2)-IXCORD(TOWER).LE.0.AND.MCOORD(1)-IYCORD(TOWER).LE.0)I
     1QUAD = 3
```

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C             FORTRAN  IV   G       MAIN  PROGRAM


      IF(MCOORD(2)-IXCORD(TOWER).GE.0.AND.MCOORD(1)-IYCORD(TOWER).LE.0)I
     1QUAD = 4
      JOANNE =  (20*(TOWER-1)+1)+(5*IQUAD-5)  +((HORIZN/5)-1)
      CALL GREG
      IF(YEL.LE.RING(JOANNE,4))GO TO 730
      ATOWER(ITOWER)=ATOWER(ITOWER)+1.
C     COMPUTE THE BURNING TIME IF DISCOVERED BY TOWER
      IF(TIME.GT.6.OR.TIME.LE.19)IBURNT=0
      IF(TIME.LE.6)IBURNT=7-TIME
      IF(TIME.GT.19)IBURNT=24-TIME+7
      GO TO 750
  730 IBURNT=7777
      IF(TOWER-NTOWER)1001,750,750
 1001 INK = TOWER + 1
      GO TO 1000
 2018 IBCB = 1
      GO TO 649

C     GOT TO THIS POINT ONLY IF IFIDA = 0
C     CHECK FOR FLYING CODE CRITERIA

 2019 IF(MATT - 1)9998,2099,9999
 9998 IF(BCFNDX - IB)9997,2099,2099
 9997 IF(CAUSE - IC)9999,2099,9999

C     GOT TO THIS POINT ONLY IF ONE OR MORE FIRES ON THIS DAY

C     THIS SECTION CHECKS THE FLYING CODE TO SEE IF AIRCRAFT FLY TODAY

  750 IF(MATT - 1)725,2099,727
  725 IF(BCFNDX-IB)1300,2016,2016
 1300 IF(CAUSE.NE.IC)GO TO 727
 2016 IF(XCOUNT - 1.)2099,2099,2096
 2096 IF(CAUSE .EQ. IC) GO TO 2099
      GO TO 727
 2099 DO 2020 I = 1,NROUTE
      IF(ROUTE(I,MCOUNT+1)-1.)2020,2021,2021
 2021 DAYSA = DAYSA + (ROUTE(I,7)/ROUTE(I,9))*ROUTE(I,10)
      AA$=AA$+(ROUTE(I,7)/ROUTE(I,9))*ROUTE(I,10)
 2020 CONTINUE
      IF(IFIDA.EQ.0)GO TO 9999


C     THIS IS THE START OF THE AIR ROUTE ROUTINE

      DO 749 J=1,NROUTE
      IF(ROUTE(J,MCOUNT+1)-1.)747,746,746
  747 IBCYD(J)=0
      GO TO 749
  746 IBCYD(J)=1
  749 CONTINUE
      KINK=1
```

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C               FORTRAN  IV   G        MAIN  PROGRAM


 4444 DO 743 J=KINK,NROUTE
      KDEX=J
      IF(IEOYD(J).EQ.0)GO TO 743
      MAXIE=ROUTE(J,11)
      DO 742 LEG=1,MAXIE
      IMAXIE=LEG

C     CHECK FOR FLIGHT LEG ANGLE

      ITHETA=23+(LEG-1)*12
      IF(ROUTE(J,ITHETA).EQ.0.)GO TO 741
      IF(ROUTE(J,ITHETA).EQ.90.)GO TO 740

C     WE KNOW THE LEG IS SLOPED SINCE THE TWO PREVIOUS IF STATEMENTS WERE FALSE

      IF(ROUTE(J,ITHETA).LE.45.)GO TO 739

C     THIS SECTION IS FOR AN AIR ROUTE SLOPED GREATER THAN 45 DEGREES

      RADIAN=ROUTE(J,ITHETA)/57.296
      FIREY=MCOORD(1)
      XLINE=(FIREY-ROUTE(J,ITHETA-2))/ROUTE(J,ITHETA-1)
      FIREX=MCOORD(2)
      DELTAX=ABS(FIREX-XLINE)
      SIGHT=DELTAX*SIN(RADIAN)
      ISIGHT=SIGHT
      JAM=192+4*(IMAXIE-1)
      MAM=193+4*(IMAXIE-1)
      KAM=194+4*(IMAXIE-1)
      NAM=195+4*(IMAXIE-1)
      IF(HORIZN-ISIGHT)742,1451,1451
 1451 IF(ROUTE(KDEX,JAM).LE.FIREX.AND.FIREX.LE.ROUTE(KDEX,KAM).OR.ROUTE
     1(KDEX,JAM).GE.FIREX.AND.FIREX.GE.ROUTE(KDEX,KAM).AND.ROUTE(KDEX,
     1MAM).LE.FIREY.AND.FIREY.LE.ROUTE(KDEX,NAM).OR.ROUTE(KDEX,MAM).GE.
     1FIREY.AND.FIREY.GE.ROUTE(KDEX,NAM))GO TO 724
      GO TO 742

C     THIS SECTION IS FOR AN AIR ROUTE SLOPED LESS THAN 45 DEGREES

  739 RADIAN=ROUTE(J,ITHETA)/57.296
      FIREX=MCOORD(2)
      YLINE=ROUTE(J,ITHETA-2)+ROUTE(J,ITHETA-1)*FIREX
      FIREY=MCOORD(1)
      DELTAY=ABS(FIREY-YLINE)
      SIGHT=DELTAY*COS(RADIAN)
      ISIGHT=SIGHT
      JAM=192+4*(IMAXIE-1)
      MAM=193+4*(IMAXIE-1)
      KAM=194+4*(IMAXIE-1)
      NAM=195+4*(IMAXIE-1)
      IF(HORIZN-ISIGHT)742,1452,1452
 1452 IF(ROUTE(KDEX,JAM).LE.FIREX.AND.FIREX.LE.ROUTE(KDEX,KAM).OR.ROUTE
     1(KDEX,JAM).GE.FIREX.AND.FIREX.GE.ROUTE(KDEX,KAM).AND.ROUTE(KDEX,
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C              FORTRAN  IV   G        MAIN  PROGRAM

      1MAM).LE.FIREY.AND.FIREY.LE.ROUTE(KDEX,NAM).OR.ROUTE(KDEX,MAM).GE.
      1FIREY.AND.FIREY.GE.ROUTE(KDEX,NAM))GO TO 724
       GO TO 742

C      THIS SECTION IS FOR A VERTICAL AIR ROUTE , THETA=90

   740 XLINE=ROUTE(J,ITHETA-2)
       FIREX=MCOORD(2)
       SIGHT=ABS(XLINE-FIREX)
       ISIGHT=SIGHT
       MAM=193+4*(IMAXIE-1)
       NAM=195+4*(IMAXIE-1)
       IF(HORIZN-ISIGHT)742,1453,1453
  1453 IF(ROUTE(KDEX,MAM).LE.FIREY.AND.FIREY.LE.ROUTE(KDEX,NAM).OR.ROUTE
      1(KDEX,MAM).GE.FIREY.AND.FIREY.GE.ROUTE(KDEX,NAM))GO TO 724
       GO TO 742

C      THIS SECTION IS FOR A HORIZONTAL AIR ROUTE , THETA=0

   741 YLINE=ROUTE(J,ITHETA-2)
       FIREY=MCOORD(1)
       SIGHT=ABS(YLINE-FIREY)
       ISIGHT=SIGHT
       KAM=194+4*(IMAXIE-1)
       JAM=192+4*(IMAXIE-1)
       IF(HORIZN-ISIGHT)742,1454,1454
  1454 IF(ROUTE(KDEX,JAM).LE.FIREX.AND.FIREX.LE.ROUTE(KDEX,KAM).OR.ROUTE
      1(KDEX,JAM).GE.FIREX.AND.FIREX.GE.ROUTE(KDEX,KAM))GO TO 724
   742 CONTINUE
   743 CONTINUE
       IF(IBURNT.EQ.7777) GO TO 738
C      IF THE IBURNT VALUE IS 7777, THE FIRE WAS NOT DISCOVERED BY TOWER
       IDELT=IBURNT
       GO TO 731


C      THIS SECTION DETERMINES WHICH LEG THE FIRE OCCURRED ON, CALCULATES THE
C      VALUE OF IBURNA, AND ALSO CHECKS TO MAKE SURE THE FIRE STARTED BEFORE
C      THE AIRCRAFT ARRIVED ON THE SCENE

   724 IRANK=DIST-1
       AROUTE(KDEX)=AROUTE(KDEX)+1.
       AIRDIS=0.
       TOTAL=0.
       DO 723 L=1,IMAXIE
       JAR=12*(L-1)
       DO 722 N=1,9
       JARR=(N+11)+JAR
       AIRDIS=AIRDIS+ROUTE(KDEX,JARR)
       LLL=JARR+IRANK
       IF(L.EQ.IMAXIE.AND.N.EQ.1)TOTAL=ROUTE(KDEX,LLL)
   722 CONTINUE
```

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C              FORTRAN  IV   G        MAIN  PROGRAM

   723 CONTINUE
       AIRDIS=AIRDIS-(TOTAL/2.)
       BURNA=AIRDIS/ROUTE(KDEX,9)
       CLOCK=ROUTE(KDEX,8)+BURNA
       ICLOCK=CLOCK
       IF(ICLOCK-TIME)4442,4443,4443
  4442 IF(KDEX.EQ.NROUTE) GO TO 727
       KINK=KDEX+1
       GO TO 4444
  4443 IF(ICLOCK.GE.TIME) IBURNA=ICLOCK-TIME
       IF(IBURNT.EQ.0)GO TO 726
       IF(IBURNA.LT.IBURNT)GO TO 729
       IDELT=IBURNT
       GO TO 731
   729 IDELT=IBURNA
       TEAD=TEAD+1.
       BROUTE(KDEX)=BROUTE(KDEX)+1.
       GO TO 731
   726 IDELT=0
       GO TO 731
   727 IBURNA=9999
       IF(IBURNT.EQ.7777) GO TO 738
       IDELT=IBURNT
       GO TO 731


C      THIS SECTION DETERMINES THE TIME IT TAKES THE PUBLIC TO FIND THE FIRE

   738 CALL GREG
       DO 736 K = 1,25
       INDEX = K
       IF(K.EQ.1)GO TO 735
       IF(K.EQ.25)GO TO 733
       IF(YFL.GT.PUBLIC(FUEL,K-1).AND.YFL.LE.PUBLIC(FUEL,K))GO TO 734
       GO TO 736
   735 IF(YFL.LE.PUBLIC(FUEL,K))GO TO 734
   736 CONTINUE
   733 IBURNP = 30
       GO TO 732
   734 IBURNP = INDEX
   732 IDELT = IBURNP
       SNPP=SNPP+1.


C      THIS SECTION CALCULATES THE SIZE OF THE FIRE WHEN IT IS DISCOVERED

   731 ACRES = 0.
       IF(IDELT - 1)8100,8101,8101
  8100 IDELT = 1
       GO TO 8102
  8101 IDELT = IDELT + 1
  8102 DO 721 IGROW = 1,IDELT
```

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C              FORTRAN  IV   G        MAIN  PROGRAM


          ISTAR = IGROW - 1
          TTTIME = TIME + ISTAR
          IF(TTTIME.GT.24.AND.TTTIME.LT.49)TTTIME = TTTIME - 24
          IF(TTTIME .GT. 48)TTTIME = TTTIME - 48
          ACRES = ACRES + ((SPREAD(FUEL,BURNDX,TTTIME))**2)/(40. * 3.14728)
      721 CONTINUE
          IF(MCCUNT-1)8501,8501,8502
     8501 TACRES=TACRES+ACRES
          GO TO 8503
     8502 TTACRE=TTACRE+ACRES


C         THIS SECTION CALCULATES THE SUPPRESSION COST OF THE FIRE

     8503 IF(ACRES.LE..25)I=1
          IF(ACRES.GT..25.AND.ACRES.LE.1.45)I=2
          IF(ACRES.GT.1.45.AND.ACRES.LE.2.45)I=3
          IF(ACRES.GT.2.45.AND.ACRES.LE.3.45)I=4
          IF(ACRES.GT.3.45.AND.ACRES.LE.4.45)I=5
          IF(ACRES.GT.4.45.AND.ACRES.LE.5.45)I=6
          IF(ACRES.GT.5.45.AND.ACRES.LE.6.45)I=7
          IF(ACRES.GT.6.45.AND.ACRES.LE.7.45)I=8
          IF(ACRES.GT.7.45.AND.ACRES.LE.8.45)I=9
          IF(ACRES.GT.8.45.AND.ACRES.LE.9.45)I=10
          IF(ACRES.GT.9.45.AND.ACRES.LE.10.45)I=11
          IF(ACRES.GT.10.45.AND.ACRES.LE.25.00)I=12
          IF(ACRES.GT.25.00.AND.ACRES.LE.100.00)I=13
          IF(ACRES.GT.100.00.AND.ACRES.LE.500.00)I=14
          IF(ACRES.GT.500.00)I=15
          IF(MCCUNT -1)8504,8504,8505
     8504 AMAY(I) = AMAY(I) + 1.
          GO TO 8506
     8505 REST(I) = REST(I) + 1.
     8506 RSIZE(I) = RSIZE(I) + 1.
          CALL GREG
          DO 1402 J=1,11
          INDEX=J
          IF(J.EQ.1)GO TO 1403
          IF(J.EQ.11)GO TO 1404
          IF(YFL.GT.PCOST(I,J-1).AND.YFL.LE.PCOST(I,J))GO TO 1404
          GO TO 1402
     1403 IF(YFL.LE.PCOST(I,J))GO TO 1404
     1402 CONTINUE
     1404 SPCCST=AMONIQ(INDEX)
          CRANGE(INDEX) = CRANGE(INDEX) + 1.
          DRANGE(INDEX)=DRANGE(INDEX)+1.
          IF(FIDAYS(KKKK)-XKOUNT)652,652,6
      652 XKOUNT=0.
     9999 CONTINUE
          DO 7699 J=1,11
          CTS(J)=CAU(J)*DRANGE(J)
     7699 CONTINUE
```

```
C               FORTRAN  IV   G       MAIN  PROGRAM


      DO 7698 J=1,11
      BT$=BT$+GT$(J)
 7698 CONTINUE
C     THIS SECTION CALCULATES THE COST TO OPERATE THE TOWERS FOR A SEASON

      WDEX = NDEX
      WTOWER = NTOWER
      T$ = WTOWER * COSTT

C     THIS SECTION IS RESERVED FOR THE CALCULATION OF DAMAGE

      D$=0.
      X(NDEX)=T$+AA$+D$+BT$
      IF(NDEX.GE.50)GO TO 6499
      GO TO 8888


C     THIS SECTION DEFINES THE STOPPING RULE FOR THE MODEL AND CALCULATES
C     THE STATISTICS REQUIRED

 6499 DO 6498 J=1,NDEX
      XXBAR=XXBAR+X(J)
 6498 CONTINUE
      XBAR = XXBAR/WDEX
      DO 6497 J=1,NDEX
      VARR=(X(J)-XBAR)**2
      VVAR=VVAR+VARR
 6497 CONTINUE
      VAR = VVAR/(WDEX - 1.)
      SIGMA=VAR**.5
      D = ZALPHA *(SIGMA / WDEX**.5)
      GDEX=NDEX
      BIGN=(ZALPHA**2*VAR)/D**2
      IF(GDEX.GE.BIGN)GO TO 6496
      IF(NDEX.EQ.200)GO TO 5540
      GO TO 5539
 5540 ZALPHA = (D*WDEX**.5)/SIGMA
      GO TO 6496


C     THIS SECTION ELIMINATES AUTOCORRELATION IN THE RANDOM NUMBER GENERATOR

 5539 CALL GREG
      AX = IIX
      AIX = YFL * AX
      IIX = AIX
      IIX = IIX +3
      IIX = (IIX/2) * 2  + 1
      IX = IIX
      CALL GREG
 8888 CONTINUE
```

```
C              FORTRAN  IV   G       MAIN  PROGRAM


C      THIS IS THE START OF THE PRINT ROUTINE FOR THE FIRST PAGE OF OUTPUT

 6496 WRITE(6,2000)
      WRITE(6,2002) FORES1,FORES2,FORES3,FORES4,FORES5
      WRITE(6,2004) ALT1,ALT2,ALT3,ALT4,ALT5,ALT6,ALT7,ALT8,ALT9,ALT10
      WRITE(6,2084)
 2084 FORMAT(1H0,48X,'CODES USED IN COMPUTER PROGRAM')
      WRITE(6,2085)
 2085 FORMAT(//1H ,6X,'FOREST DISTRICT CODE',14X,'FUEL  CODE',22X,'SPREA
     1D INDEX CODE',10X,'BUILDUP INDEX CODE')
      WRITE(6,2086)
 2086 FORMAT(1H0,9X,'1',5X,'DF1',21X,'1',5X,'CONIFEROUS',19X,'1',6X,'0-1
     1',19X,'1',6X,'0-9')
      WRITE(6,2087)
 2087 FORMAT(1H ,9X,'2',5X,'DF3',21X,'2',5X,'MIXED WOOD',19X,'2',6X,'2-9
     1',19X,'2',5X,'10-25')
      WRITE(6,2088)
 2088 FORMAT(1H ,9X,'3',5X,'DF5',21X,'3',5X,'LICHEN AND MUSKEG',12X,'3',
     15X,'10-19',18X,'3',5X,'26-50')
      WRITE(6,2089)
 2089 FORMAT(1H ,9X,'4',5X,'DF6',21X,'4',5X,'GRASS',24X,'4',5X,'20 PLUS'
     116X,'4',5X,'51-100')
      WRITE(6,2090)
 2090 FORMAT(1H ,9X,'5',5X,'DF7',85X,'5',5X,'100 PLUS')
      WRITE(6,2091)
 2091 FORMAT(//////1H ,6X,'BURNING INDEX CODE',16X,'MONTH CODE',22X,'FIR
     1E CAUSE CODE',19X,'TOWER NAME CODE')
      WRITE(6,2092)
 2092 FORMAT(1H0,6X,'1',6X,'1-20  LOW',19X,'1',3X,'MAY',25X,'1',5X,'OTHE
     1R INDUSTRIES',12X,'1',4X,'YATES')
      WRITE(6,2093)
 2093 FORMAT(1H ,6X,'2',5X,'21-40 MODERATE',15X,'2',3X,'JUNE',24X,'2',5X
     1,'LIGHTENING',18X,'2',4X,'STEEN RIVER')
      WRITE(6,2094)
 2094 FORMAT(1H ,6X,'3',5X,'41-60 HIGH',19X,'3',3X,'JULY',24X,'3',5X,'SE
     1TTLEMENT',18X,'3',4X,'AMBER')
      WRITE(6,2095)
 2095 FORMAT(1H ,6X,'4',5X,'61-80 VERY HIGH',14X,'4',3X,'AUGUST',22X,'4'
     1,5X,'WOOD INDUSTRIES',13X,'4',4X,'ADAIR')
      WRITE(6,5396)
 5396 FORMAT(1H ,6X,'5',5X,'81-100 EXTREME',15X,'5',3X,'SEPTEMBER',19X,'
     15',5X,'RECREATION',18X,'5',4X,'ZAMA')
      WRITE(6,2097)
 2097 FORMAT(1H ,73X,'6',5X,'INCENDIARY',18X,'6',4X,'BASSET')
      WRITE(6,2098)
 2098 FORMAT(1H ,73X,'7',5X,'PUBLIC PROJECT',14X,'7',4X,'WATT MOUNTAIN')
      WRITE(6,5399)
 5399 FORMAT(1H ,73X,'8',5X,'MISCELLANEOUS KNOWN',9X,'8',4X,'RAINBOW')
      WRITE(6,3000)
 3000 FORMAT(1H ,73X,'9',5X,'MISCELLANEOUS UNKNOWN',7X,'9',4X,'WHITESAND
     1S')
      WRITE(6,3001)
```

```
C             FORTRAN  IV   G       MAIN  PROGRAM


 3001 FORMAT(1H ,72X,'10',5X,'RAILROAD',19X,'10',4X,'PONTON')
      WRITE(6,3002)
 3002 FORMAT(1H ,6X,'AIR ROUTE CODE',21X,'SECTOR CODE',54X,'11',4X,'FOGG
     1Y MOUNTAIN')
      WRITE(6,3003)
 3003 FORMAT(1H ,106X,'12',4X,'LAMBERT CREEK')
      WRITE(6,3004)
 3004 FORMAT(1H ,6X,'1',5X,'ROUTE 64 SPRING',15X,'1',5X,'FIRST  QUADRANT
     1',43X,'13',4X,'BUFFALO')
      WRITE(6,3005)
 3005 FORMAT(1H ,6X,'2',5X,'ROUTE 21 SUMMER',15X,'2',5X,'SECOND QUADRANT
     1',43X,'14',4X,'WADLIN')
      WRITE(6,3006)
 3006 FORMAT(1H ,6X,'3',5X,'ROUTE 22 SUMMER',15X,'3',5X,'THIRD  QUADRANT
     1',43X,'15',4X,'PANNY')
      WRITE(6,3007)
 3007 FORMAT(1H ,6X,'4',5X,'ROUTE 23 SUMMER',15X,'4',5X,'FOURTH QUADRANT
     1',43X,'16',4X,'TALBOT LAKE')
      WRITE(6,3008)
 3008 FORMAT(1H ,6X,'5',5X,'ROUTE 24 SUMMER',79X,'17',4X,'BISON LAKE')
      WRITE(6,3009)
 3009 FORMAT(1H ,106X,'18',4X,'HAWK HILLS')
      WRITE(6,3010)
 3010 FORMAT(1H ,106X,'19',4X,'JEAN LAKE')
      WRITE(6,3011)
 3011 FORMAT(1H ,41X,'RING    CODE',53X,'20',4X,'WOLVERINE')
      WRITE(6,8300)
 8300 FORMAT(1H ,106X,'21',4X,'PETITOT')
      WRITE(6,3012)
 3012 FORMAT(1H ,42X,'1',6X,'5 MILE RADIUS',44X,'22',4X,'DUMMY')
      WRITE(6,3013)
 3013 FORMAT(1H ,42X,'2',5X,'10 MILE RADIUS')
      WRITE(6,3014)
 3014 FORMAT(1H ,42X,'3',5X,'15 MILE RADIUS')
      WRITE(6,3015)
 3015 FORMAT(1H ,42X,'4',5X,'20 MILE RADIUS')
      WRITE(6,3016)
 3016 FORMAT(1H ,42X,'5',5X,'25 MILE RADIUS')


C      THIS IS THE START OF THE PRINT ROUTINE FOR THE SECOND PAGE OF OUTPUT

      WRITE(6,2000)
 2000 FORMAT(1H1,30X,'PROTOTYPE  FOREST  FIRE  DETECTION  DESIGN  MODEL'
     1)
      WRITE(6,2002) FORES1,FORES2,FORES3,FORES4,FORES5
 2002 FORMAT(1H ,41X,5A4,2X,'FOREST')
      WRITE(6,2004) ALT1,ALT2,ALT3,ALT4,ALT5,ALT6,ALT7,ALT8,ALT9,ALT10
 2004 FORMAT(1H ,13X,'DESIGN  ALTERNATIVE - - - - - - - - - - - -   ',10A
     14)
      WRITE(6,2005)
 2005 FORMAT(1H ,41X,'DESIGN          CHARACTERISTICS')
```

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C              FORTRAN  IV   G        MAIN  PROGRAM

 2010 WRITE(6,2011)NTOWER,SPRING,SUMMER,NAIR
 2011 FORMAT(1H ,3X,'NUMBER OF TOWERS    ',I4,3X,'NUMBER OF AIR ROUTES SP
     1RING  ',I4,2X,'SUMMER  ',I4,2X,'MAXIMUM NUMBER OF AIRCRAFT REQUIRE
     1D',I8)
      WRITE(6,2012)JSEX
 2012 FORMAT(1H ,29X,'NUMBER OF FIRE SEASONS RUN BEFORE CUTOFF',I10)
      WRITE(6,2013)
 2013 FORMAT(1H0,39X,'FOREST      COST      SUMMARY')
      IF(NTOWER -0)2015,2014,2015
 2014 AVG$T = 0.
      GO TO 2022
 2015 ZTOWER = NTOWER
      AVG$T = ZTOWER * COSTT
 2022 ADEX = JSEX
      AVG$A = DAY$A/ADEX
      DESIGN = AVG$T + AVG$A
      WRITE(6,2023)DESIGN
 2023 FORMAT(1H ,44X,'AVERAGE  TOTAL  COST  OF  THIS  DETECTION  DESIGN'
     1,14X,'$',F12.0)
      WRITE(6,2024)
 2024 FORMAT(1H ,43X,'SUPPRESSION   COST   SUMMARY')
      WRITE(6,2025)
 2025 FORMAT(1H ,7X,'FIRE',6X,'$')
      WRITE(6,2026)
 2026 FORMAT(1H ,4X,'COST',10X,'CATEGORY',5X,'NUMBER',22X,'CATEGORY')
      WRITE(6,2027)
 2027 FORMAT(1H ,4X,'RANGE',5X,'AVERAGE USED',6X,'OF FIRES',3X,'PROBABIL
     1ITY',6X,'TOTAL  $')
      DO 2029 J = 1,11
      RANGE = RANGE + CRANGE(J)
 2029 CONTINUE
      DO 2030 J = 1,11
      PRANGE(J) = CRANGE(J) / RANGE
 2030 CONTINUE
      DO 2031 J = 1,11
      SUMPR = SUMPR + PRANGE(J)
 2031 CONTINUE
      DO 2032 J = 1,11
      CT$(J) = CAU(J) * CRANGE(J)
 2032 CONTINUE
      DO 2033 J = 1,11
      ST$ = ST$ + CT$(J)
 2033 CONTINUE
      WRITE(6,2035) CAU(1),CRANGE(1),PRANGE(1),CT$(1)
 2035 FORMAT(1H ,2X,'NO DATA',7X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
      WRITE(6,2036)CAU(2),CRANGE(2),PRANGE(2),CT$(2)
 2036 FORMAT(1H ,5X,'1-100',6X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
      WRITE(6,2037) CAU(3),CRANGE(3),PRANGE(3),CT$(3)
 2037 FORMAT(1H ,3X,'101-500',6X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
      WRITE(6,2038) CAU(4),CRANGE(4),PRANGE(4),CT$(4)
 2038 FORMAT(1H ,3X,'501-1000',5X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
      WRITE(6,2039)CAU(5),CRANGE(5),PRANGE(5),CT$(5)
```

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C              FORTRAN  IV   G       MAIN  PROGRAM

  2039 FORMAT(1H ,2X,'1001-5000',5X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
       WRITE(6,2040)CAU(6),CRANGE(6),PRANGE(6),CT$(6)
  2040 FORMAT(1H ,2X,'5001-10000',4X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
       WRITE(6,2041) CAU(7),CRANGE(7),PRANGE(7),CT$(7)
  2041 FORMAT(1H ,1X,'10001-25000',4X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
       WRITE(6,2042)CAU(8),CRANGE(8),PRANGE(8),CT$(8)
  2042 FORMAT(1H ,1X,'25001-50000',4X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
       WRITE(6,2043)CAU(9),CRANGE(9),PRANGE(9),CT$(9)
  2043 FORMAT(1H ,1X,'50001-75000',4X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
       WRITE(6,2044) CAU(10),CRANGE(10),PRANGE(10),CT$(10)
  2044 FORMAT(1H ,1X,'75001-100000',3X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
       WRITE(6,2045)CAU(11),CRANGE(11),PRANGE(11),CT$(11)
  2045 FORMAT(1H ,1X,'100000 + ',6X,F7.0,7X,F7.0,6X,F5.4,9X,F9.0)
       WRITE(6,2046) RANGE,SUMPR,ST$
  2046 FORMAT(1H0,19X,'TOTALS',4X,F8.0,5X,F6.4,7X,'$',F10.0)
       ACTS = ST$ / ADEX
       WRITE(6,2047) ACTS
  2047 FORMAT(1H ,44X,'AVERAGE   TOTAL COST OF SUPPRESSION FOR THIS DESIG
      1N',12X,'$',F12.0)
       ACTD = 0.
       WRITE(6,2048) ACTD
  2048 FORMAT(1H ,44X,'AVERAGE   TOTAL COST OF DAMAGE FOR THIS DESIGN',17
      1X,'$',F12.0)
       BIGTOT = DESIGN + ACTS + ACTD
       WRITE(6,5395)  BIGTOT
  5395 FORMAT(1H0,35X,'AVERAGE SEASONAL TOTAL COST OF DETECTION + SUPPRES
      1SION + DAMAGE',9X,'$',F12.0)
       WRITE(6,2049)
  2049 FORMAT(//1H ,4X,'FOREST',3X,'FIRE',4X,'SIZE',4X,'SUMMARY',6X,'FORE
      1ST',7X,'CAUSE',9X,'SUMMARY',10X,'FOREST',5X,'VISIBILITY',4X,'SUMMA
      1RY')
       WRITE(6,2050)
  2050 FORMAT(1H0,3X,'SIZE',9X,'NUMBER',3X,'PROBABILITY',8X,'CAUSE',15X,'
      1NUMBER   IN',6X,'PROBABILITY',9X,'VISIBILITY',2X,'NUMBER',2X,'PROB
      1ABILITY')
       WRITE(6,2051)
  2051 FORMAT(1H ,' CATEGORY         IN       FOR EACH         CATEGORY
      1           CATEGORY        FOR EACH                 IN           OF
      1 FOR EACH')
       WRITE(6,2052)
  2052 FORMAT(1H ,3X,'ACRES',8X,'CATEGORY',3X,'CATEGORY',46X,'CATEGORY',1
      11X,'MILES',7X,'DAYS',6X,'CATEGORY')
       DO 2054 J = 1,15
       SRSIZE = SRSIZE + RSIZE(J)
  2054 CONTINUE
       DO 2055 J = 1,15
       PSIZE(J) = RSIZE(J) / SRSIZE
  2055 CONTINUE
       DO 2056 J = 1,15
       SPSIZE = SPSIZE + PSIZE(J)
  2056 CONTINUE
       DO 2058 J = 1,10
```

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C               FORTRAN  IV   G        MAIN  PROGRAM

      SRCS = SRCS + RCS(J)
 2058 CONTINUE
      DO 2059 J = 1,10
      PRCS(J) = RCS(J) / SRCS
 2059 CONTINUE
      DO 2060 J = 1,10
      SPRCS = SPRCS + PRCS(J)
 2060 CONTINUE
      DO 2062 J = 1,6
      SRV = SRV + RV(J)
 2062 CONTINUE
      DO 2063 J = 1,6
      PRV(J)=RV(J)/SRV
 2063 CONTINUE
      DO 2064 J = 1,6
      SPRV = SPRV + PRV(J)
 2064 CONTINUE
      WRITE(6,2065)RSIZE(1),PSIZE(1),RCS(1),PRCS(1),RV(1),PRV(1)
 2065 FORMAT(1H0,4X,'SPOT',8X,F7.0,4X,F6.4,10X,'OTHER INDUSTRIES',5X,F9.
     10,9X,F6.4,12X,' 0',8X,F7.0,6X,F6.4)
      WRITE(6,2066)RSIZE(2),PSIZE(2),RCS(2),PRCS(2),RV(2),PRV(2)
 2066 FORMAT(1H ,3X,'.25-1.45',5X,F7.0,4X,F6.4,10X,'LIGHTENING',11X,F9.0
     1,9X,F6.4,12X,' 5',8X,F7.0,6X,F6.4)
      WRITE(6,2067)RSIZE(3),PSIZE(3),RCS(3),PRCS(3),RV(3),PRV(3)
 2067 FORMAT(1H ,2X,'1.46-2.45',5X,F7.0,4X,F6.4,10X,'SETTLEMENT',11X,F9.
     10,9X,F6.4,12X,'10',8X,F7.0,6X,F6.4)
      WRITE(6,2068)RSIZE(4),PSIZE(4),RCS(4),PRCS(4),RV(4),PRV(4)
 2068 FORMAT(1H ,2X,'2.46-3.45',5X,F7.0,4X,F6.4,10X,'WOOD INDUSTRIES',6X
     1,F9.0,9X,F6.4,12X,'15',8X,F7.0,6X,F6.4)
      WRITE(6,2069)RSIZE(5),PSIZE(5),RCS(5),PRCS(5),RV(5),PRV(5)
 2069 FORMAT(1H ,2X,'3.46-4.45',5X,F7.0,4X,F6.4,10X,'RECREATION',11X,F9.
     10,9X,F6.4,12X,'20',8X,F7.0,6X,F6.4)
      WRITE(6,2070)RSIZE(6),PSIZE(6),RCS(6),PRCS(6),RV(6),PRV(6)
 2070 FORMAT(1H ,2X,'4.46-5.45',5X,F7.0,4X,F6.4,10X,'INCENDIARY',11X,F9.
     10,9X,F6.4,12X,'25',8X,F7.0,6X,F6.4)
      WRITE(6,2071)RSIZE(7),PSIZE(7),RCS(7),PRCS(7)
 2071 FORMAT(1H ,2X,'5.46-6.45',5X,F7.0,4X,F6.4,10X,'PUBLIC PROJECT',7X
     1,F9.0,9X,F6.4)
      WRITE(6,2072)RSIZE(8),PSIZE(8),RCS(8),PRCS(8)
 2072 FORMAT(1H ,2X,'6.45-7.45',5X,F7.0,4X,F6.4,10X,'MISCELLANEOUS KNOWN
     1',2X,F9.0,9X,F6.4)
      WRITE(6,2073)RSIZE(9),PSIZE(9),RCS(9),PRCS(9)
 2073 FORMAT(1H ,2X,'7.46-8.45',5X,F7.0,4X,F6.4,10X,'MISCELLANEOUS UNKNO
     1WN',F9.0,9X,F6.4)
      WRITE(6,2074)RSIZE(10),PSIZE(10),RCS(10),PRCS(10)
 2074 FORMAT(1H ,2X,'8.46-9.45',5X,F7.0,4X,F6.4,10X,'RAILROAD',13X,F9.0,
     19X,F6.4)
      WRITE(6,2075)RSIZE(11),PSIZE(11)
 2075 FORMAT(1H ,2X,'9.46-10.45',4X,F7.0,4X,F6.4)
      WRITE(6,2076)RSIZE(12),PSIZE(12)
 2076 FORMAT(1H ,1X,'10.46-25.00',4X,F7.0,4X,F6.4)
      WRITE(6,2077)RSIZE(13),PSIZE(13)
```

```
C               FORTRAN  IV   G        MAIN  PROGRAM


 2077 FORMAT(1H ,1X,'25.01-100.00',3X,F7.0,4X,F6.4)
      WRITE(6,2078) RSIZE(14),PSIZE(14)
 2078 FORMAT(1H ,'100.01-500.00',3X,F7.0,4X,F6.4)
      WRITE(6,2079)RSIZE(15),PSIZE(15)
 2079 FORMAT(1H ,'500.00 +',8X,F7.0,4X,F6.4)
      WRITE(6,2080)SRSIZE,SPSIZE,SRCS,SPRCS,SRV,SPRV
 2080 FORMAT(1H0,6X,'TOTALS',3X,F8.0,4X,F6.4,22X,'TOTALS',2X,F10.0,9X,F6
     1.4,11X,'TOTALS',4X,F8.0,6X,F6.4)
      DO 8507 J=1,15
      TAMAY=TAMAY+AMAY(J)
      TREST=TREST+REST(J)
 8507 CONTINUE
      APSAD=TACRES/TAMAY
      PISS=TTACRE/TREST
      WRITE(6,2081)APSAD
 2081 FORMAT(1H ,2X,'MAY AVERAGE FIRE SIZE AT DISCOVERY',F8.2,2X,'ACRES
     1')
      WRITE(6,8508) PISS
 8508 FORMAT(1H ,2X,'AVERAGE FIRE SIZE AT DISCOVERY EXCLUDING MAY FIRES'
     1,F8.2,2X,'ACRES')
      IF(NTOWER.EQ.1)GO TO 9297
      DO 4001 J=1,NTOWER
      TSNFD=TSNFD+ATOWER(J)
 4001 CONTINUE
      DO 4002 J=1,NTOWER
      PNFD(J)=ATOWER(J)/TSNFD
 4002 CONTINUE
      DO 4003 J=1,NTOWER
      TPNFD=TPNFD+PNFD(J)
 4003 CONTINUE
      DO 4004 J=1,NTOWER
      PTFD(J)=ATOWER(J)/SRSIZE
 4004 CONTINUE
      DO 4005 J=1,NTOWER
      TPTFD=TPTFD+PTFD(J)
 4005 CONTINUE
 9297 IF(MATT.EQ.2)GO TO 9299
      DO 4006 J=1,NROUTE,NREPET
      TSNFA=TSNFA+AROUTE(J)
 4006 CONTINUE
      DO 4008 J=1,NROUTE,NREPET
      PSNFA(J)=AROUTE(J)/TSNFA
 4008 CONTINUE
      DO 4009 J=1,NROUTE,NREPET
      TPSNFA=TPSNFA+PSNFA(J)
 4009 CONTINUE
      DO 4010 J=1,NROUTE,NREPET
      PTFDA(J)=AROUTE(J)/SRSIZE
 4010 CONTINUE
      DO 4011 J=1,NROUTE,NREPET
      TPTFDA=TPTFDA+PTFDA(J)
 4011 CONTINUE
```

```
C              FORTRAN  IV   G        MAIN  PROGRAM

  9299 TPTFDP=SNFP/SBSIZE
       DO 4012 J=1,4
       TOTALG=TOTALG+AIFUEL(J)
  4012 CONTINUE
       DO 4014 J=1,4
       PGREAT(J)=AIFUEL(J)/TOTALG
  4014 CONTINUE
       DO 4015 J=1,4
       GREAT=GREAT+PGREAT(J)
  4015 CONTINUE


C      THIS SECTION STARTS THE PRINT ROUTINE FOR THE THIRD PAGE OF OUTPUT

       WRITE(6,2000)
       WRITE(6,2002)FORES1,FORES2,FORES3,FORES4,FORES5
       WRITE(6,2004)ALT1,ALT2,ALT3,ALT4,ALT5,ALT6,ALT7,ALT8,ALT9,ALT10
       WRITE(6,4016)
  4016 FORMAT(1H0,48X,'TOWER   DISCOVERY   SUMMARY')
       WRITE(6,4017)
  4017 FORMAT(1H0,9X,'TOWER',10X,'TOWER',18X,'NUMBER  OF  ','FIRES  DISCO
      1VERED',7X,'PERCENT OF TOWER',5X,'PERCENT OF TOTAL')
       WRITE(6,4018)
  4018 FORMAT(1H ,10X,'CODE',11X,'NAME',57X,'DISCOVERIES',9X,'FIRE DISCOV
      1ERIES',//)
       DO 4019 J=1,NTOWER
       WRITE(6,4020)ITC(J),TOWER1(J),TOWER2(J),TOWER3(J),TOWER4(J),TOWER5
      1(J),ATOWER(J),PNFD(J),PTFD(J)
  4020 FORMAT(1H ,11X,I2,5X,5A4,21X,F7.0,23X,F7.2,15X,F7.3)
  4019 CONTINUE
       WRITE(6,4021)TSNFD,TPNFD,TPTFD
  4021 FORMAT(1H0,47X,'TOTAL',6X,F8.0,9X,'TOTAL',9X,F7.2,7X,'TOTAL',3X,F7
      1.3)
       WRITE(6,4022)TPTFD
  4022 FORMAT(1H0,72X,'PERCENT OF TOTAL FIRES DISCOVERED BY TOWERS',9X,F7
      1.3)


C      THIS SECTION STARTS THE PRINT ROUTINE FOR THE FOURTH PAGE OF OUTPUT

       WRITE(6,2000)
       WRITE(6,2002)FORES1,FORES2,FORES3,FORES4,FORES5
       WRITE(6,2004)ALT1,ALT2,ALT3,ALT4,ALT5,ALT6,ALT7,ALT8,ALT9,ALT10
       WRITE(6,4023)
  4023 FORMAT(1H0,47X,'AIRCRAFT   DISCOVERY   SUMMARY')
       WRITE(6,4024)
  4024 FORMAT(1H0,26X,'AIR ROUTE',6X,'NUMBER OF FIRES',6X,'PERCENT OF AIR
      1 ROUTE',5X,'PERCENT OF TOTAL')
       WRITE(6,4025)
  4025 FORMAT(1H ,28X,'NUMBER',6X,'OCCURRING ON ROUTE',10X,'OCCURRENCES',
      18X,'FIRE OCCURRENCES',//)
       DO 4026 J=1,NROUTE,NREPET
```

```
C               FORTRAN  IV   G       MAIN  PROGRAM


      WRITE(6,4027)ROUTE(J,1),AROUTE(J),PSNFA(J),PTFDA(J)
 4027 FORMAT(1H ,29X,F4.0,13X,F7.0,17X,F5.2,17X,F5.2)
 4026 CONTINUE
      WRITE(6,4028)TSNFA,TPSNFA,TPTFDA
 4028 FORMAT(1H ,38X,'TOTAL',2X,F8.0,8X,'TOTAL',2X,F7.2,9X,'TOTAL',F8.2)
      WRITE(6,4029)TPTFDA
 4029 FORMAT(1H ,66X,'PERCENT OF TOTAL FIRES OCCURRING ON AIR ROUTES',3X
     1,F7.3,///)
      IF(MATT.EQ.2)GO TO 9298
      DO 5598 J=1,NROUTE
      PSNFA2(J)=BROUTE(J)/TEAD
 5598 CONTINUE
      DO 5597 J=1,NROUTE
      PTFDA2(J)=BROUTE(J)/SRSIZE
 5597 CONTINUE
 9298 PEFFCT=TEAD/SRSIZE
      WRITE(6,4024)
      WRITE(6,4025)
      DO 5599 J=1,NROUTE
      WRITE(6,4027) ROUTE(J,1),BROUTE(J),PSNFA2(J),PTFDA2(J)
 5599 CONTINUE
      DO 5596 J=1,NROUTE
      TPSNF2=TPSNF2+PSNFA2(J)
 5596 CONTINUE
      DO 5595 J=1,NROUTE
      TPTFD2=TPTFD2+PTFDA2(J)
 5595 CONTINUE
      WRITE(6,4028)TEAD,TPSNF2,TPTFD2
      WRITE(6,5594)PEFFCT
 5594 FORMAT(1H0,62X,'EFFECTIVE PERCENT OF FIRES DISCOVERED BY AIR ROUTE
     1S',11X,F7.3,///)
      WRITE(6,4030)
 4030 FORMAT(1H0,46X,'PUBLIC   DISCOVERY   SUMMARY')
      WRITE(6,4031)SNFP,TPTFDP
 4031 FORMAT(1H0,9X,'TOTAL NUMBER OF FIRES DISCOVERED BY PUBLIC',9X,F9.0
     1,3X,'PERCENT OF TOTAL FIRES DISCOVERED BY PUBLIC',9X,F7.3)
      SUMMY=TPTFD+PEFFCT+TPTFDP
      WRITE(6,4032)SUMMY
 4032 FORMAT(1H0,112X,'TOTAL',7X,F7.3)


C     THIS SECTION STARTS THE PRINT ROUTINE FOR THE FIFTH PAGE OF OUTPUT

      WRITE(6,2000)
      WRITE(6,2002)FORES1,FORES2,FORES3,FORES4,FORES5
      WRITE(6,2004)ALT1,ALT2,ALT3,ALT4,ALT5,ALT6,ALT7,ALT8,ALT9,ALT10
      WRITE(6,4033)
 4033 FORMAT(1H0,52X,'FIRE   IN   FUELS   SUMMARY')
      WRITE(6,4034)
 4034 FORMAT(1H0,34X,'FUEL   TYPE',7X,'NUMBER OF FIRES',8X,'PROBABILITY'
     1)
      WRITE(6,4035)AIFUEL(1),PGREAT(1)
```

```
C              FORTRAN  IV   G       MAIN  PROGRAM


 4035 FORMAT(1H0,33X,'CONIFEROUS',13X,F8.0,14X,F6.2)
      WRITE(6,4036)AIFUEL(2),PGREAT(2)
 4036 FORMAT(1H0,33X,'MIXED WOOD',13X,F8.0,14X,F6.2)
      WRITE(6,4037)AIFUEL(3),PGREAT(3)
 4037 FORMAT(1H0,33X,'LICHEN - MUSKEG',8X,F8.0,14X,F6.2)
      WRITE(6,4038)AIFUEL(4),PGREAT(4)
 4038 FORMAT(1H0,33X,'GRASS',18X,F8.0,14X,F6.2)
      WRITE(6,4039)TOTALG,GREAT
 4039 FORMAT(1H0,47X,'TOTAL',3X,F9.0,6X,'TOTAL',2X,F7.2)
      WRITE(6,5550)
 5550 FORMAT(////1H0,43X,'STATISTICS   FOR   THIS   RUN')
      WRITE(6,5549)XBAR
 5549 FORMAT(1H0,13X,'XBAR',10X,'=',3X,F13.0,8X,'= ','AVERAGE TOTAL SEAS
     1ONAL COST')
      WRITE(6,5548)VAR
 5548 FORMAT(1H0,13X,'VARIANCE',6X,'=',3X,F13.0)
      WRITE(6,5547) SIGMA
 5547 FORMAT(1H0,13X,'STD DEVIATION',1X,'=',3X,F13.0)
      WRITE(6,5546) D,ZALPHA
 5546 FORMAT(1H0,13X,'LENGTH OF CONFIDENCE INTERVAL =',3X,F12.0,5X,'AT
     1Z  =',F7.4)
      STOP
      END


C     THIS SECTION IS THE RANDOM NUMBER GENERATOR

      SUBROUTINE GREG
      COMMON IX,IY,YFL
      IY=IX*65539
      IF(IY)5,6,6
    5 IY=IY+2147483647+1
    6 YFL=IY
      YFL=YFL*.4656613E-9
      IX = -IY
      RETURN
      END
END OF FILE
```

BIGN	The N value in the stopping rule equation.
BIGTOT	Average seasonal total cost of suppression + detection + damage.
BROUTE	Same as AROUTE except for an individual season only.
BTAB1	The spread index versus buildup index table for the spring and summer. The rows are the 4 spread categories and the columns are the 5 buildup index categories. The values in the matrix are the 5 burning index categories.
BTAB2	The spread index versus buildup index table for the fall. The rows are the 4 spread categories and the columns are the 5 buildup index categories. The 5 burning index categories are in the matrix.
BT$	The seasonal cost of suppression.
BUPDEX	The buildup index for the day.
BURNA	The time it takes to fly from the airport to the fire location.
BURNDX	The burning index for the day as a function of spread and buildup.
CAU	A vector of average suppression costs for each of the 11 cost categories used.
CAUSE	The cause of the fire starting.
CLOCK	The time of day the aircraft arrives at the spot the fire occurs.
COSTT	The average yearly cost to operate a lookout tower.
CRANGE	The number of fires falling in each cost category.
CT$	The total suppression dollars for each cost category.
CUMP1	An intermediate variable calculated to identify the upper range of SPOT data.
CUMP2	An intermediate variable calculated to identify the lower range of SPOT data.

D	A variable in the stopping rule called the confidence interval.
D$	The cost of damage for a season.
DAY$A	The totalizer of the cost of aircraft detection for the total run.
DELTAX	The horizontal distance from the fire to the air route on the map.
DELTAY	The vertical distance from the fire to the air route on the map.
DESIGN	The average total detection cost.
DIST	The ranger district being considered.
DRANGE	The number of fires in each cost category for a season.
FIDAYS	The daily fire count for all the days in a season.
FIRE	The fire count for the number of fires in a season.
FIREX	See MCOORD (2).
FIREY	See MCCORD (1).
FORES1 - FORES2	The name of the forest. This is printed at the top of each page of output.
FUEL	The fuel the fire is burning in.
GREAT	Total percentage of fires in each fuel: i.e. 100%.
GREG	The subroutine that calculates a random number between 0 and 1.
GT$	The seasonal cost of suppression for each category.
HORZN	The visibility in miles.
I	An index used to categorize the fire sizes.
IB	This is the minimum value of the burning index that initiates aircraft flying.
IBOB	A check to ensure the aircraft fly even on days with no fires.

IBOYD	A vector of the 5 months filled with 1 or 0. If 1 route used, if 0 not used.
IBURNA	The elapsed time from fire start until an aircraft discovery.
IBURNP	The elapsed time from fire start until a public discovery.
IBURNT	The elapsed time from fire start until a tower discovery.
IC	This is the value of the cause that initiates aircraft.
ICLOCK	See CLOCK.
IDC	This is the district the fire is located in.
IDELT	The elapsed time between fire start and discovery as used by the growth model.
IDIST	The recoded value of DIST so the numbers run from 1 to 5 for indexing.
IFIDA	The variable that takes on the value of the number of fires for each day.
IFIRE	Integer value of FIRE.
IGROW	An intermediate variable calculated to determine the value of TTTIME.
IIX	See AIX.
IMAXIE	The current air route leg being flown.
INK	A counter used to ensure all the towers are used in searching for the fire.
IQUAD	The tower quadrant the fire is located in.
IRANK	An intermediate variable used in determining the value of TOTAL.
ISEX	The maximum number of fire seasons the simulation will run.
ISIGHT	See SIGHT.
ISTAR	An intermediate variable calculated to determine the value of TTTIME .

ITC	The tower code number.
ITHETA	The minimum angle between an air route leg and the X axis (horizontal line).
ITOWER	See TOWER.
IX	The value used to initiate the random variable generator GREG.
IXCORD	The X coordinate of the tower.
IY	An intermediate variable used in the random number generator.
IYCORD	The Y coordinate of the tower.
JAM	The index calculated to check to lower X limit of the air route line.
JAR	An intermediate variable created to locate the correct AIRDIS for each leg.
JARR	An intermediate variable created to locate the correct AIRDIS for each route.
JOANNE	An intermediate variable calculated to locate the correct row in the RING MATRIX.
JSEX	See ISEX.
KAM	The index calculated to check the upper X limit of the air route line.
IDEX	The current air route being tested.
KEY	A counter used to aid in reading in RING data.
KINK	An index counter used to check that all the air routes are flown during the day.
KK	An index that takes on the value of 1 or 2 to aid in determining SPOT.
KKK	The instantaneous counter of the day of the season.
KKKK	The total counter for the number of days in a season.
LEG	An index counter used to determine the angle of the air route leg.

LENGTH	The distance from a tower to the fire.
LLL	An intermediate variable calculated to aid in determining TOTAL.
MAM	The index calculated to check to lower Y limit of the air route line.
MARK	An intermediate variable used to calculate the cause and fuel values.
MATT	The flying code criteria used to determine when aircraft fly. If MATT = 0, check the values of IB and IC; if MATT = 1, fly every day; if MATT = 2, never fly.
MAXIE	The number of legs on an air route.
MCODE	The code for the month from 1 to 5.
MCOORD(1)	The X coordinate of the fire location.
MCOORD(2)	The Y coordinate of the fire location.
MCOUNT	The month counter.
MDIANE	An intermediate variable used in determining the correct row in the PCDIST matrix.
MM	An intermediate variable used to limit in the determination of fire location.
MMMM	A seasonal counter to keep track of the number of seasons run.
MONTH	The month.
NAIR	The number of aircraft required to fly all the air routes at the designed times. Used in print out only.
NAM	The index calculated to check the upper Y limit on the air route line.
NDAYS	The number of days in the fire season.
NDEX	The number of the current fire season run.
NREPET	Correction variable to offset the double counting of fires on air routes. When NROUTE = 5, NREPET = 1. When NROUTE = 10, NREPET = 2. When NROUTE = 15, NREPET = 3.

NROUTE	The number of aircraft routes in the design.
NROW	A variable calculated to determine which row to use in the SPOT data.
NTOWER	The number of towers in the design.
PB1-PB5	The cumulative probabilities of each of the buildup indices.
PCDIST	A matrix of the probability data for fire cause given the district and month. The rows are the districts for each month and the columns are the cumulative probability data for the 10 cause categories.
PCOST	A matrix of the cumulative suppression probabilities for each of the 15 size categories.
PEFFCT	Effective percent of fires discovered by air routes.
PFDIST	This is the fuel probability data. The matrix has the fuel type for each district in each month as the rows and the cumulative probability for the fuels as the columns.
PFIRE	A vector of the cumulative probabilities for a fire for each day of the fire season.
PGREAT	Percentage of fires occurring in each fuel.
PISS	The average fire size at discovery excluding May fires.
PNFD	Percentage of tower-discovery fires discovered by each tower.
PNFIRE	This is the cumulative probability for the number of fires occurring during the fire season.
PRANGE	The probability of a fire falling in each cost category.
PRCS	The probability of a fire being caused by each of the cause categories.
PRV	The probability of a day having each of the visibility categories.
PS1-Ps4	The cumulative probabilities of the spread indices.
PSIZE	The probability of a fire occurring in each size category.
PSNFA	Percent of fires falling on each air route.

PSNFA2	Percent of aircraft-discovery fires falling on each air route.
PTFD	Percent of total fires discovered by each tower.
PTFDA	Percent of total fires falling on each air route.
PTFDA2	Effective percent of total fires falling on each air route.
PTIME	A matrix of the probability data for the starting time of each fire given the cause of fire. The rows are the 10 causes and the columns are the 25 time categories.
PUBLIC	A matrix of the 4 different fuel categories versus the cumulative time probabilities for each of 25 time categories the public requires to detect a fire.
RADIAN	The value of theta in radians.
RANGE	The total number of fires over the entire run.
RCS	The number of fires falling in each cause category.
REST	An accumulator for fires in each size category not in May.
RING	This is the blind area data for each tower. It is in the form of a matrix.
ROUTE	A matrix of the air route data for each air route. The matrix will accomodate 15 air routes with a maximum of 15 legs on each route.
RSIZE	The number of fires in each size category.
RV	The number of days that fall into each visibility category.
SIGHT	The perpendicular distance from a fire to an air route.
SIGMA	The standard deviation about the total mean cost.
SNFP	The total number of fires discovered by the public.
SPCOST	The average cost of suppression.
SPOT	A matrix of coordinates describing the dimensions of the 5 districts of the Footner Forest.

SPRCS	The total probability of each cause category; i.e. 1.00
SPRDEX	The daily spread index.
SPREAD	The cubic matrix for the C values of the fire growth model. The I values are the 4 fuels. The J values are the 5 burning indices and the K values are the 25 time categories.
SPRING	The number of air routes flown in the spring.
SPRV	The total probability of all of the visibility categories; i.e. 1.00 .
SPSIZE	The total probability of all the size categories; i.e. 1.00 .
SRCS	The total number of fires during the entire run.
SRSIZE	The total number of fires in all size categories.
SRV	The total number of days in the entire run.
ST$	The total suppression dollars spent during the entire run.
SUM	The total of the frequency distribution when TIME was unknown.
SUMMER	The number of summer air routes being used.
SUMMY	The total percent of all fires discovered; i.e. 100%.
SUMPR	The total probability of fires falling in each cost category; ie.e 1.00.
TACRES	The total acres burnt during the entire run.
TANAY	An accumulator that sums the AMAY values.
T$	The cost of operating the tower for a season.
TEAD	The total number of fires discovered by aircraft.
TIME	The time of day the fire starts.
TOTAL	The length of the discovery leg in the district in which the fire occurred.
TOTALG	Total number of fires in the 4 fuel categories.

TOWER	The tower that finds the fire.
TOWER1 - TOWER5	This is the name of the tower; i.e. Yates.
TPNFD	The total percent of tower discoveries made by towers; i.e. 100%.
TPSNFA	The total percent of fires on air routes that were located on routes; i.e. 100%.
TPSNF2	The total percent of aircraft discovery fires falling on air routes; i.e. 100%.
TPTFD	The total percent of fires discovered by towers.
TPTFD2	The percent of all fires that were discovered by aircraft.
TPTFDA	The percent of all fires that fell on air routes.
TPTFDP	Percent of total fires discovered by the public.
TREST	An accumulator that sums the REST values.
TSNFA	The total number of fires starting on air routes.
TSNFD	The total number of fires discovered by towers.
TTACRE	The total acres burnt during each season.
TTTIME	The hours through which the growth model operates.
VAR	The variance of the total cost distribution over the total run.
VARR	An intermediate variable used to determine the value of VAR.
VIS	The visibility data given the spread index for each day of the fire season. The rows are the spread index categories and the columns are the cumulative probabilities for the 6 visibility categories.
VVAR	An intermediate variable used to determine the value of VAR.
WDEX	See NDEX.
WHERE	A matrix of probability data for the district the fire is located in. The rows are the months, the columns the cumulative probability for each district.

WTOWER	See NTOWER.
X	The total costs for each season.
XBAR	The mean of the total cost distribution.
SKOUNT	A daily counter internal to each season.
SLINE	The X value of the route line when the Y value is coincident with the Y coordinate of the fire.
XN	The percentage of frequencies for each of the time categories.
XNORML	The summation of the percentages of the time categories equals 100%.
XXBAR	The summation of all the total seasonal costs.
YFL	The value of the random variable being generated.
YLINE	The Y value of the route line when the X value is coincident with the X coordinate of the fire.
ZALPHA	The percentile of the normal distribution which leaves alpha/2 % probability in each tail.
ZTOWER	See NTOWER.

APPENDIX D

A LISTING OF THE DATA

```
$SIGNON GAVM 'LIST'
ON AT  23:12.43 ON 04-10-72  LAST ON AT  09:18.33
$LIST *SOURCE*

                DATA DECK SET UP     FORTRAN IV  G


          THIS IS A LISTING OF THE DATA THAT WAS USED TO DRIVE THE MODEL.
         UNDER EACH VARIABLE NAME IS THE NUMERICAL VALUES THAT WERE USED FOR
         THE FOCTNER FOREST.THEY ARE SHOWN HERE EXACTLY THE WAY THEY APPEAR
         ON THE DATA CARDS.


                  NREPET
 1

                  NAIR
  2

                  ZALPHA
09500

                  IX
  76231491

                  CAU
    25    48   268   742  2059  6956 14650 34094 60666 87857285294

                  COSTT
      6000

                  SPRING,SUMMER
  1 4

                  ALT1------------------------ALT10
19 TOWERS - FLY EVERY DAY

                  FORES1---------------------FORES5
FOOTNER

                  PNFIRE
     33115

                  MATT
  1

                  IC
  2

                  IB
  2

                  NROUTE
  5

                  NTOWER
19



```

```
             DATA DECK SET UP     FORTRAN IV  G


               ISEX
0200

               NDAYS
153

               AMONIQ
     25     48    268     742    2059    6956   14650   34094   60666   87857 285294

               PCOST
 203 428 698 820 987100020003000400050006000
 152 239 478 630 967 989100020003000400050000
 087 130 260 303 825 868 955100020003000400000
 227 272 317 453 908100020003000400050006000
 001 125 250 251 875100020003000400050006000
 042 043 168 251 834 959100020003000400050000
 333 334 500 501 833100020003000400050006000
 333 334 335 667100020003000400050006000700
 001 002 143 429 715100020003000400050006000
 001 250 500 501100020003000400050006000700
 040 080 200 360 760 880 881 920 921 9601000
 040 160 400 401 720 880 960100020003000400
 001 087 174 348 739 740 870 957 958 9591000
 001 002 063 188 438 563 751 939 940 9411000
 001 002 003 004 005 006 007 008 009 5001000

               ROUTE
641000024413120 48 7
0540000220000000000000000000000950000704008000000000000000000000000189000090
 26000000000000000000000000  30   3419 40000000000000000000000000- 67   9343
 24    10                  +082-0016 9       37                  +005+  6533
       24                  +165-006433




106103181107181107181099181099158090158090130063130063096068096068126089
1260891061030000000000000000000000000000000000000000000000000000000000000000
00000000000000000000000000000000000
210111141714120 4810
0000004300000000000000000000261-  17360027000000000000000000000000 151-  7336
 65000000000000000000000000  55     00 31000000000000000000000000 219     90
 45                        +086     00 15                        +173     90
 31                        +071     00 30                        +195     90
 60                        +014+001207 38    38                  +306-021465



102110129069129069149040149040214040214040214086214086166086166086166070
1660702000702000702000412000411420341420341021100000000000000000000000000
000000000000000000000000000000000000
```

```
                DATA DECK SET UP     FORTRAN IV  G

220111127411120 48 7
00000001400000000000000000000078   191100000002600000000800000000000168-  7336
0000000300000000005000000000006200009000000004800000000000000000000000900000000
       30        5         +015     90                  58        +121+003821
       18     27  5        +216-011549




10211009010509010506012606012606009006009001409001409001412701412706814 5
068145102110000000000000000000000000000000000000000000000000000000000000
000000000000000000000000000000000000
230111136411120 48 8
0000000130000370000000000000-058   1485603400000000000290000000000000001520000000
01000000000000000000000000002060000900510000000000000000000000000001390000000
 14                        +150     90 63                              +127     00
 15                        +218     90 82    24                        +101+000503




102110129150129150193150193150193141193141141141141141141127141127207127
207127207114207114102110000000000000000000000000000000000000000000000000
00000000000000000000000000000000000
240111135014120 48 9
0000000000000000000035000000160000191100000000000000000047010000000001490003620
0000000000000000160280000000014000009000000000000000000000560000000199000000 0
                  12       +239-006232                         74      +192     00
                  19       +168     90                         55      +171     00
                   9       +309-013353



101179066171066171012154012154012197012197067197067197077190077190152190
152190152172152172106172106172101179000000000000000000000000000000000000
00000000000000000000000000000000000

               PUBLIC
 3790 4600 5410 6760 7300 7301 7302 7570 7840 8110 8111 8380 8381 8382 8650 8651
 8920 8921 8922 8923 9190 9460 9461 973010000
 4197 6133 7744 8388 9354 9355 9356 9357 9358 9359 9360 9361 9362 9363 9364 9365
 9366 9367 9368 9677 9678 9679 9680 968110000
 2382 2859 3814 4769 5724 5725 5726 5727 5728 5729 5730 6200 6201 6202 6203 6204
 6205 6206 6207 6676 6677 7630 7631 953210000
 5292 7644 7645 7646 7647 8233 8234 8235 8236 8237 8238 8239 8240 8241 8242 8243
 8244 8245 8246 8247 8248 8249 8822 941110000
```

```
            DATA DECK SET UP     FORTRAN IV  G


              IDC,TOWER1,ETC
7YATES                1131197
7STEEN RIVER         2 77180
6AMBER               3 19148
6ADAIR               4 55147
3ZAMA                5 30108
3BASSET              6 64 80
3WATI MOUNTAIN       7 91111
3RAINBOW             8 11 90
1WHITE SANDS         9184165
1PONTON             10137131
1FOGGY MOUNTAIN     11181114
1LAMBERT CREEK      12206 70
1BUFFALO            13137 64
1WADLIN             14159 52
9PANNY              15212 10
9TALBOT LAKE        16150 22
9BISON LAKE         17118  5
9HAWK HILLS         18 92 43
9JEAN LAKE          19217 32

              RING
11 50000
11100000
11150000
11200000
11250000
12 50000
12100000
12150000
12200000
12250000
13 50000
13100000
13150000
13200073
13250238
14 50000
14100000
14150000
14200000
14250000
21 50204
21100646
21150388
21200131
21250164
22 50000
22100239
22150684
```

```
                DATA DECK SET UP     FORTRAN IV  G


    22200815
    22250755
    23 50000
    23100408
    23150612
    23200378
    23250272
    24 50593
    24100556
    24150000
    24200000
    24250000
    31 50286
    31100102
    31150102
    31200036
    31250196
    32 50255
    32100409
    32150429
    32200679
    32251000
    33 50000
    33100000
    33150000
    33200000
    33250000
    34 50000
    34100000
    34150000
    34200000
    34250000
    41 50000
    41100000
    41150368
    41200254
    41250294
    42 50000
    42100000
    42150000
    42200204
    42250385
    43 50000
    43100000
    43150327
    43200319
    43250181
    44 50000
    44100000
    44150265
```

DATA DECK SET UP FORTRAN IV G

```
44200291
44250294
51 50000
51100000
51150000
51200102
51250113
52 50000
52100068
52150082
52200058
52250051
53 50000
53100136
53150122
53200123
53250113
54 50000
54100000
54150000
54200000
54250000
61 50120
61100273
61150000
61200000
61250000
62 50000
62100000
62150048
62200095
62250068
63 50000
63100000
63150500
63200760
63250500
64 50000
64100000
64150000
64200000
64250000
71 50613
71100727
71150674
71200393
71250000
72 50306
72100375
72150000
```

DATA DECK SET UP FORTRAN IV G

```
72200000
72250000
73 50407
73100153
73150000
73200000
73250000
74 50816
74100272
74150000
74200000
74250000
81 50407
81100000
81150164
81200181
81250045
82 50204
82100204
82150250
82200500
82250500
83 50000
83100545
83150250
83200000
83250000
84 50203
84100340
84150000
84200000
84250000
91 50000
91100000
91150500
91200333
91251000
92 50000
92100000
92150000
92200000
92250000
93 50000
93100000
93150000
93200145
93250475
94 50000
94100000
94150082
```

```
                    DATA DECK SET UP     FORTRAN IV  G


   94200043
   94250306
  101 50000
  101100000
  101150000
  101200218
  101250362
  102 50510
  102100693
  102150775
  102200635
  102250351
  103 50900
  103100409
  103150000
  103200000
  103250000
  104050407
  104100625
  104150204
  104200276
  104250113
  111 50795
  111100864
  111150886
  111200855
  111250835
  112 50000
  112100102
  112150530
  112200680
  112251000
  113 50000
  113100000
  113150123
  113200087
  113250068
  114 50204
  114100000
  114150000
  114200000
  114250000
  121 50000
  121100000
  121150000
  121200000
  121250000
  122 50000
  122100000
  122150000
```

```
                    DATA DECK SET UP     FORTRAN IV  G


    122200087
    122250136
    123 50000
    123100000
    123150307
    123200798
    123251000
    124 50000
    124100000
    124150000
    124200000
    124250000
    131 50000
    131100000
    131150000
    131200000
    131250000
    132 50000
    132100000
    132150000
    132200000
    132250000
    133 50000
    133100728
    133150755
    133200766
    133250750
    134 50000
    134100443
    134150673
    134200826
    134250886
    141 50900
    141100340
    141150000
    141200000
    141250000
    142 50388
    142100795
    142150450
    142200203
    142250159
    143 50000
    143100136
    143150367
    143200752
    143250637
    144 50500
    144100136
    144150000
```

```
                    DATA DECK SET UP     FORTRAN IV  G


     144200000
     144250000
     151 51000
     151101000
     151150000
     151200000
     151250100
     152 51000
     152101000
     152150000
     152200400
     152250700
     153 51000
     153101000
     153151000
     153201000
     153251000
     154 51000
     154101000
     154151000
     154201000
     154251000
     161 50000
     161100000
     161150000
     161200000
     161250020
     162 50400
     162100500
     162150800
     162200950
     162250800
     163 51000
     163101000
     163151000
     163201000
     163251000
     164 51000
     164101000
     164151000
     164201000
     164251000
     171 51000
     171101000
     171151000
     171200000
     171250000
     172 51000
     172101000
     172151000
```

DATA DECK SET UP FORTRAN IV G

```
172200000
172250000
173 51000
173101000
173151000
173201000
173251000
174 51000
174101000
174151000
174201000
174251000
181 51000
181101000
181150000
181200000
181250000
182 51000
182101000
182151000
182201000
182251000
183 51000
183101000
183151000
183201000
183251000
184 51000
184101000
184150000
184200000
184250000
191 51000
191101000
191151000
191201000
191251000
192 51000
192100000
192150000
192200100
192250330
193 51000
193100000
193150050
193200000
193250000
194 51000
194101000
194151000
194201000
194251000
```

```
                DATA DECK SET UP     FORTRAN IV  G


                     PFDIST
  4400 6300 630110000
  3070 6140 845010000
  5000 5001 500210000
  2500 2501 500010000
  8000 80011000020000
  5000 6750 925010000
  3100 7940 966010000
  417C 5C00 917010000
  4122 6472 941210000
  3620 4540 970010000
  5360 6074 921410000
  7850 85651000020000
  875010C002000030000
  3570 50C5 928510000
  6000 6C011000020000
  3640 9C90 909110000
 00000 5560 890010000
  3751 7502 906210000
  3751 7502 906210000
  6250 75001000020000
 00000 85711000020000
 00000 85711000020000
 00000 85711000020000
 00000 85711000020000
 00000 85711000020000

                     MONTH,MCODE,ETC
 MAY 01 1 714 857100C2000 9291000200030004000
 MAY 01 2 667 73410002000 9331000200030004000
 MAY 01 3 556 557 8341000 9441000200030004000
 MAY 01 4 526 527 6311000 7891000200030004000
 MAY 01 5 565 652 9561000 7831000200030004000
 MAY 01 6 619 714 8571000 762 905100020003000
 MAY 01 7 667 668 8751000 792 917100020003000
 MAY 01 8 679 680 8581000 750 964100020003000
 MAY 01 9 655 724 9311000 690 966100020003000
 MAY 0110 515 545 7871000 667 97C100020003000
 MAY 0111 444 583 8331000 694 944100020003000
 MAY 0112 417 473 7791000 667 917100020003000
 MAY 0113 703 757 8651000 676 865100020003000
 MAY 0114 622 838 9461000 649 86510002C003000
 MAY 0115 526 684 9211000 632 869100020003000
 MAY 0116 342 395 6841000 605 789100020003000
 MAY 0117 308 487 8721000 513 795100020003000
 MAY 0118 564 641 7441000 590 82110002C003000
 MAY 0119 405 513 6481000 486 810100020003000
 MAY 0120 350 575 7251000 400 82510002CC03000
 MAY 0121 282 538 7941000 333 769100020003000
 MAY 0122 225 425 9001000 200 675 97510002000
```

```
                 DATA DECK SET UP     FORTRAN IV  G


MAY 0123 175 325 8501000 175 650 97510002000
MAY 0124 167 405 7861000 190 642 95210002000
MAY 0125 357 571 7851000 143 548 90510002000
MAY 0126 571 714 9521000 214 571 90410002000
MAY 0127 524 714 8811000 238 643 90510002000
MAY 0128 429 691 9051000 214 595 92810002000
MAY 0129 429 691 9051000 190 595 92810002000
MAY 0130 190 595 9051000 190 619 88110002000
MAY 0131 071 357 7861000 167 596 88210002000
JUNE02 1 091 296 8311000 205 637 91010002000
JUNE02 2 114 387 8421000 182 614 90910002000
JUNE02 3 227 727 9321000 159 591 90910002000
JUNE02 4 295 590 9311000 182 614 88710002000
JUNE02 5 295 772 9311000 159 591 86410002000
JUNE02 6 341 705 9101000 159 523 81810002000
JUNE02 7 114 523 8871000 159 500 79510002000
JUNE02 8 136 681 9311000 136 454 77210002000
JUNE02 9 273 88710002000 159 432 79610002000
JUNE0210 140 698 9071000 140 419 79110002000
JUNE0211 250 72710002000 136 431 79510002000
JUNE0212 182 637 9091000 114 387 77310002000
JUNE0213 227 79510002000 114 364 75010002000
JUNE0214 114 263 8641000 114 319 70510002000
JUNE0215 122 390 8781000 098 318 68410002000
JUNE0216 220 708 9031000 146 268 68310002000
JUNE0217 262 810 9051000 019 286 71510002000
JUNE0218 415 781 9761000 122 366 75610002000
JUNE0219 190 690 9521000 119 357 76210002000
JUNE0220 190 690 8801000 119 333 71410002000
JUNE0221 279 814 9771000 093 302 74410002000
JUNE0222 381 83310002000 095 333 76210002000
JUNE0223 395 79010002000 116 372 79110002000
JUNE0224 186 674 9761000 116 372 76710002000
JUNE0225 214 571 9281000 095 357 738 9521000
JUNE0226 190 666 9761000 095 381 714 9521000
JUNE0227 419 768 9771000 116 369 625 9511000
JUNE0228 279 90710002000 163 349 675 9541000
JUNE0229 186 651 9301000 163 349 744 9531000
JUNE0230 146 707 9511000 122 342 757 9521000
JULY03 1 140 745 9781000 093 326 698 9541000
JULY03 2 233 74510002000 093 302 628 9541000
JULY03 3 364 81910002000 114 387 728 9551000
JULY03 4 318 79510002000 136 363 77210002000
JULY03 5 341 659 9771000 136 318 795 9771000
JULY03 6 116 628 8841000 116 349 768 9771000
JULY03 7 250 86410002000 136 363 81810002000
JULY03 8 386 886 9771000 159 454 84010002000
JULY03 9 295 79510002000 159 500 81810002000
JULY0310 318 75010002000 205 546 88710002000
JULY0311 364 728 9781000 182 546 88710002000
```

```
                 DATA DECK SET UP     FORTRAN IV  G

JULY0312 341 659 9541000 295 590 93210002000
JULY0313 636 93110002000 318 591 93210002000
JULY0314 727 97710002000 386 681 93110002000
JULY0315 571 90410002000 381 667 93310002000
JULY0316 302 790 9761000 302 697 93010002000
JULY0317 465 907 9771000 372 628 93010002000
JULY0318 341 81810002000 341 727 93210002000
JULY0319 209 744 9771000 279 721 68110002000
JULY0320 227 704 9311000 227 659 86410002000
JULY0321 500 84110002000 250 682 88710002000
JULY0322 256 698 9761000 256 675 88410002000
JULY0323 295 818 9771000 250 591 86410002000
JULY0324 442 761 9471000 349 651 88410002000
JULY0325 419 86110002000 419 675 95410002000
JULY0326 250 72710002000 432 682 95510002000
JULY0327 488 90710002000 372 72110002003000
JULY0328 500 955 9781000 364 70510002003000
JULY0329 341 773 9781000 409 70410002003000
JULY0330 341 81810002000 341 705 95510002000
JULY0331 386 79510002000 455 682 95510002000
AUG 04 1 477 86310002000 432 682 93210002000
AUG 04 2 310 881 9521000 381 691 95310002000
AUG 04 3 227 93210002000 227 704 95410002000
AUG 04 4 452 90410002000 286 667 95310002000
AUG 04 5 273 93210002000 250 636 93110002000
AUG 04 6 405 92910002000 190 642 90410002000
AUG 04 7 659 977 9781000 159 636 97710002000
AUG 04 8 256 79110002000 163 675 95410002000
AUG 04 9 190 642 9521000 143 595 95210002000
AUG 0410 227 568 9541000 114 523 93210002000
AUG 0411 159 682 9551000 114 478 91010002000
AUG 0412 227 863 9771000 114 409 88610002000
AUG 0413 136 636 9541000 114 364 90910002000
AUG 0414 233 75410002200 116 349 90810002000
AUG 0415 372 90710002000 116 325 88610002000
AUG 0416 409 93210002000 136 341 88610002000
AUG 0417 119 69010002000 119 262 88110002000
AUG 0418 273 773 9781000 114 228 88710002000
AUG 0419 364 659 9541000 114 228 91010002000
AUG 0420 386 545 9091000 114 228 84210002000
AUG 0421 256 768 9771000 116 256 88410002000
AUG 0422 209 72110002000 116 232 88310002000
AUG 0423 167 738 9761000 119 238 881 0002000
AUG 0424 310 78610002000 143 262 88110002000
AUG 0425 419 861 9771000 209 535 90710002000
AUG 0426 674 90710002000 326 582 90810002000
AUG 0427 659 92710002000 268 634 90210002000
AUG 0428 707 95110002000 293 610 91710002000
AUG 0429 537 927 9761000 268 634 92710002000
AUG 0430 537 85410002000 244 601 90310002000
```

```
                 DATA DECK SET UP     FORTRAN IV  G


AUG 0431 436 846 9741000 205 590 92310002000
SEPT05 1 486 97210002000 189 621 91810002000
SEPT05 2 486 918 9721000 162 621 91810002000
SEPT05 3 595 94810002000 162 594 91810002000
SEPT05 4 622 89210002000 243 594 91810002000
SEPT05 5 694 972 9731000 250 583 88910002000
SEPT05 6 892100020003000 270 621 91810002000
SEPT05 7 595 91010002000 270 594 89110002000
SEPT05 8 378 72910002000 243 567 89110002000
SEPT05 9 194 83310002000 222 528 86110002000
SEPT0510 324 865 9731000 243 540 83710002000
SEPT0511 297 70210002000 162 513 86410002000
SEPT0512 361 86110002000 167 584 80610002000
SEPT0513 400 82910002000 171 571 80010002000
SEPT0514 457 857 9431000 200 543 82910002000
SEPT0515 500 765 9711000 176 529 82310002000
SEPT0516 457 74310002000 200 486 82910002000
SEPT0517 465 788 9701000 182 485 81810002000
SEPT0518 394 667 8491000 212 515 81810002000
SEPT0519 515 727 8481000 303 606 87910002000
SEPT0520 424 818 9091000 303 576 84910002000
SEPT0521 606 758 8491000 333 636 90910002000
SEPT0522 484 871 9681000 290 645 90310002000
SEPT0523 688 81310002000 375 719 87510002000
SEPT0524 735 941 9421000 382 735 88210002000
SEPT0525 706 79410002000 382 764 91110002000
SEPT0526 559 883 9421000 382 735 91110002000
SEPT0527 559 618 8831000 382 735 91110002000
SEPT0528 353 559 6471000 353 706 91210002000
SEPT0529 364 84910002000 303 667 90910002000
SEPT0530 594 750 9061000 313 719 90710002000

                   WHERE
01 5640 7750 8680 915010000
02 3370 5540 6410 733010000
03 4410 6270 7120 865010000
04 4520 7260 8390 871010000
05 0710 5000 5001 741010000

                   PCDIST
 0420 0630 4800 4801 6050 9590 980010002000060000
 3890 3891 7780 7781 8890 8891 945010002000060000
 6250 6251 6252 6253 7500 8750 8751 8752 875310000
 7500 7501 7502 75031000020000300004000050000060000
 8570 8571 8572 8573 8574 8575 8576 8577 857810000
 0001 5480 7740 8060 8710 9680 984010002000060000
 3250 7000 7750 8000 8750 9250 9500 975010000060000
 0001 7500 8750 8751 8752 9380 9381 9382 938410000
 3530 9410 94111000020000300004000050000600070000
 0410 9800 9801 9802 9803 9804 980510000300005000
```

```
                  DATA DECK SET UP      FORTRAN IV  G


 0001 9230 9420 9421 9610 9800 98011000020000060000
 0450 7720 8170 8171 9080 9530 95311000020000060000
 0001 7000 7001 7002 70031000020000300004000050000
 2780 9450 9451 9452 9453 9454 94551000030000050000
 0001 9380 9381 9382 9383 9384 9385 93861000030000
 0710 6070 8570 8571 9280 9281 9640 96411000020000
 2940 7060 7650 7651 8240 9420 9421 94221000020000
 0001 7140 7141 7142 71431000020000300004000050000
10000200003000040000500006000070000800009000080000
 0001 3750 3751 3752 5000 7500 7501 87501000030000
 0001 00021000020000600006000060000600006000060000
 6670 6671 8340 8341 83421000020000300004000050000
 00000000000000000000000000000000000000000000000000
 6670 6671 6672 66731000020000300004000050000040000
 2500 2501 2502 25031000020000300005000060000060000

                    SPOT
00002090000009440480000010600000002400000010600000
00001590000011700630000008600000007200000012600000
00006680000013900150000007200000013500000014000000
00005570000018600180000005400000015000000015800000
00002090000007950480000012600000072000000000000000
00006680000017900150000005600000012000000070000000
00006680000014300150000000700000001350000007000000
00005570000011400180000000880000001500000007000000
00002090000014300480000000700000001200000000000000
00002780000006550360000015300000016800000000000000

                    PTIME
00001000020000300004000050013000131006400102001530
01780024100292004570052000545005960067200723007480
0748107482074840748510000
00001000020000300040000800032000321005200052100600
00720010400181002410030200411004920054800580006690
0697007370075700761010000
00001001700017100340003410034200343006700134002010
02180031800568006680073500818009010093400951009680
0968109682096830968410000
00001000020000300040000500006000070000800009000010
00011000120001300014028600572007150071510715207153
0715407155071560715710000
00001000020000300004003000121001211015110212002121
02420039400485005150051510576006060066700697007270
0757007571078700787110000
00001017700077100772015400154101542015430180002310
02311035900523005900059010744008210082110847008980
0898109750097510975210000
00001000020000300004000050000600007000080000900010
00011000120001300014006700134001341013420134301344
0134501346013470134810000
```

```
                    DATA DECK SET UP      FORTRAN IV  G


0000100002000030000400005000060000700008000090000 10
000110100005000050010700008000080010900009001100000
20000300004000050000600000
000010000200003000040000500006000070000800009000010
000110143001431042900429104292042930429404295042960
429704298042990430010000
00001000020000300004000050000600007000080000900010
033330333106670066710667206673066740667506676066770
6678066790668006681100000

                    BTAB1
11123
12234
12345
13455

                    BTAB2
11111
11222
12234
12345

                    VIS
 11  27  35  48  68100
 00  12  20  36  57100
 00  10  18  34  56100
 00  10  20  35  54100

                    SPREAD
010010010010010010010010010010014016019022025025025022019016014010010010
080080080081081082082083084085086087088089090090090089088087086085082080
370370375380385390395400410420430440450460470470470460450440430420390375
450450455460465470475480490500510520530540550550550540530520510500470455
570570575580585590595600610620630640650660670670670660650640630620590575
010010010010010010010010010010010010010010010010010010010010010010010010
025025025026026027027028029030031032033034035035035034033032031030027025
080080080082082084084086088090092094096098100100100098096094092090084080
120120120122122124126128129130132134136138140140140138136134132130126120
180180184186190194196200204208212220224226230230230226220214210206200190
010010010010010010010010010010010010010010010010010010010010010010010010
055055055056056057057058059060061062063064065065065064063062061060057055
115115118121124127130133138143148153158163165165165163158153148143127118
170170172174176178180182186190194198202206210210210206202188184180178172
300300306310314316320322324326330334338340342346350350342338332324320310
010010010010010010010010010010016022028034040040040034028022016010010010
900900904908912918925930940950960970980990990990990975960945930925920901
990990990990990990990990990990990990990990990990990990990990990990990990
990990990990990990990990990990990990990990990990990990990990990990990990
990990990990990990990990990990990990990990990990990990990990990990990990
```

```
                  DATA DECK SET UP     FORTRAN IV  G


                     PFIRE
0000000000212300042460006369001080900108100015249001968900196900033810
 042510 058760 058761 067460 071900 075023 077146 085846 087969 106529
 113089 121789 127229 129352 131475 135915 157765 171885 178445 178446
 182885 189270 196655 201045 203035 211795 227945 238705 285505 298655
 312805 314795 319185 333335 349485 374385 383145 411445 415835 435355
 450505 452495 458875 460865 478385 530985 552885 559265 570025 574415
 585175 598385 609305 629125 644375 675175 681795 692715 695000 705920
 723440 727740 730025 734325 749575 756195 758480 780300 791220 795520
 806440 808725 811010 811011 815310 821930 830580 832865 835150 835151
 837435 839720 852820 861630 872550 883470 890020 892159 894298 898708
 905258 907397 909536 909537 913946 920496 924906 924907 924908 929316
 938126 940265 944675 951225 953364 957774 962184 964323 966462 968601
 970740 970741 972879 972880 972881 975057 975058 981617 981618 981619
 983795 983796 983797 983798 983799 983800 985973 988151 990329 990330
 992507 996887 997408 997409 997410 997929 998450 998451 998452 998453
0998454099845510000000
END OF FILE
```

APPENDIX E

COMPUTER OUTPUT GENERATED BY THE MODEL

The computer print out from a single simulation run consists of five pages of output. The first page displays the codes used throughout the program. The second page displays the relevant cost, size, cause and visibility information. The third page illustrates the information generated on the tower system and the fourth page shows the information generated on the aircraft and air route system. The fifth and last page displays information on fuels and the confidence interval for the average total seasonal cost as it is calculated by the sequential stopping rule. Each page of output was designed for a different application of the illustrated information. Table E-1 summarizes the uses of the information on each page.

An example of the output from a single run is shown at the end of this appendix. This is an example of a design alternative consisting of 19 look-out towers and one aircraft flying the spring route and four aircraft flying the summer routes. The aircraft operated on days having a burning index of 2 or greater or on days having lightening caused fires. The simulation stopped after 50 seasons as shown at the top of the second page of output. The confidence interval shown on the fifth page of output reveals that the probability is 95% that the average total seasonal cost for this

TABLE E-1

USAGE OF THE OUTPUT

PAGE NUMBER	SUMMARY CONSIDERED	OUTPUT USAGE
1	Total page	Codes for Variables used throughout main program. Information required for main program deciphering.
2	Suppression Cost	1. Test the frequency distribution for validity. 2. Compare the total costs in each category.
	Forest Fire Size	1. Test the frequency distribution for validity. 2. Presents a probability distribution to operationalize other research. 3. Compare May fires with fires occurring in other months.
	Cause	1. Test the frequency distribution for validity. 2. Compare the number of fires in each category.
	Visibility	1. Test the frequency distribution for validity.
	Average Costs of Design	1. Compare the average total cost of detection with other designs. 2. Compare the average total cost of suppression with other designs. 3. Compare the average seasonal total cost with other designs.
3	Tower Discovery	1. Evaluate the number of fires discovered by each tower. 2. Compare the number of fires discovered by towers with other detection systems.
4	Air Route Discovery	1. Evaluate the number of fires occurring on each air route.
	Aircraft Discovery	1. Evaluate number of fires discovered on each air route. 2. Compare the effective percent of fires discovered by aircraft with the percent of total fires occurring on air routes.
	Public Discovery	1. Compare the percent of total fires discovered by public with the other detection agencies.
5	Fuel	1. Test the frequency distribution for validity.
	Statistics For Run	1. Evaluate the average total seasonal cost and the length of the confidence interval.

run is \$601,826 $\pm$ \$40,360. The confidence interval is partially determined by ZALPHA. For ZALPHA equal to .95, the researcher requires a 95% confidence level. If ZALPHA was set equal to .99, the researcher would require a 99% confidence level and the confidence interval would be larger.

PROTOTYPE FOREST FIRE DETECTION DESIGN MODEL
FOOTNER FOREST
DESIGN ALTERNATIVE - - - - - - - - - - - - - - 19 TOWERS-FLY WEATHER OR CAUSE

CODES USED IN COMPUTER PROGRAM

FOREST DISTRICT CODE

1	DF1
2	DF3
3	DF5
4	DF6
5	DF7

FUEL CODE

1	CONIFEROUS
2	MIXED WOOD
3	LICHEN AND MUSKEG
4	GRASS

SPREAD INDEX CODE

1	0-1
2	2-9
3	10-19
4	20 PLUS

BUILDUP INDEX CODE

1	0-9
2	10-25
3	26-50
4	51-100
5	100 PLUS

BURNING INDEX CODE

1	1-20 LOW
2	21-40 MODERATE
3	41-60 HIGH
4	61-80 VERY HIGH
5	81-100 EXTREME

MONTH CODE

1	MAY
2	JUNE
3	JULY
4	AUGUST
5	SEPTEMBER

FIRE CAUSE CODE

1	OTHER INDUSTRIES
2	LIGHTENING
3	SETTLEMENT
4	WOOD INDUSTRIES
5	RECREATION
6	INCENDIARY
7	PUBLIC PROJECT
8	MISCELLANEOUS KNOWN
9	MISCELLANEOUS UNKNOWN
10	RAILROAD

TOWER NAME CODE

1	YATES
2	STEEN RIVER
3	AMBER
4	ADAIR
5	ZAMA
6	BASSET
7	WATT MOUNTAIN
8	RAINBOW
9	WHITESANDS
10	PONTON
11	FOGGY MOUNTAIN
12	LAMBERT CREEK
13	BUFFALO
14	WADLIN
15	PANNY
16	TALBOT LAKE
17	BISON LAKE
18	HAWK HILLS
19	JEAN LAKE
20	WOLVERINE
21	PETITOT
22	DUMMY

AIR ROUTE CODE

1	ROUTE 64 SPRING
2	ROUTE 21 SUMMER
3	ROUTE 22 SUMMER
4	ROUTE 23 SUMMER
5	ROUTE 24 SUMMER

SECTOR CODE

1	FIRST QUADRANT
2	SECOND QUADRANT
3	THIRD QUADRANT
4	FOURTH QUADRANT

RING CODE

1	5 MILE RADIUS
2	10 MILE RADIUS
3	15 MILE RADIUS
4	20 MILE RADIUS
5	25 MILE RADIUS

PROTOTYPE FOREST FIRE DETECTION DESIGN MODEL
FOOTNER FOREST

DESIGN ALTERNATIVE - - - - - - - - - - - - - 19 TOWERS-FLY WEATHER OR CAUSE

DESIGN CHARACTERISTICS

NUMBER OF TOWERS 19 NUMBER OF AIR ROUTES SPRING 1 SUMMER 4 MAXIMUM NUMBER OF AIRCRAFT REQUIRED 2
NUMBER OF FIRE SEASONS RUN BEFORE CUTOFF 50

FOREST COST SUMMARY

AVERAGE TOTAL COST OF THIS DETECTION DESIGN $ 175044.

SUPPRESSION COST SUMMARY

FIRE COST RANGE	$ CATEGORY AVERAGE USED	NUMBER OF FIRES	PROBABILITY	CATEGORY TOTAL $
NO DATA	25.	377.	.1480	9425.
1-100	48.	350.	.1374	16800.
101-500	268.	496.	.1947	132928.
501-1000	742.	276.	.1084	204792.
1001-5000	2059.	730.	.2866	1503070.
5001-10000	6956.	109.	.0428	758204.
10001-25000	14650.	80.	.0314	1172000.
25001-50000	34094.	61.	.0239	2079734.
50001-75000	60666.	0.	.0	0.
75001-100000	87857.	20.	.0079	1757140.
100000 +	285294.	48.	.0188	13694112.
	TOTALS	2547.	1.0000	$ 21328192.

AVERAGE TOTAL COST OF SUPPRESSION FOR THIS DESIGN $ 426564.
AVERAGE TOTAL COST OF DAMAGE FOR THIS DESIGN $ 0.

AVERAGE SEASONAL TOTAL COST OF DETECTION + SUPPRESSION + DAMAGE $ 601608.

FOREST FIRE SIZE SUMMARY

SIZE CATEGORY ACRES	NUMBER IN CATEGORY	PROBABILITY FOR EACH CATEGORY
SPOT	981.	0.3852
.25-1.45	522.	0.2049
1.46-2.45	113.	0.0444
2.45-3.45	124.	0.0487
3.46-4.45	63.	0.0247
4.46-5.45	35.	0.0137
5.46-6.45	43.	0.0169
6.45-7.45	53.	0.0208
7.46-8.45	7.	0.0027
8.46-9.45	20.	0.0079
9.46-10.45	19.	0.0075
10.46-25.00	145.	0.0569
25.01-100.00	216.	0.0848
100.01-500.00	164.	0.0644
500.00 +	42.	0.0165
TOTALS	2547.	1.0000

FOREST CAUSE SUMMARY

CAUSE CATEGORY	NUMBER IN CATEGORY	PROBABILITY FOR EACH CATEGORY
OTHER INDUSTRIES	377.	0.1480
LIGHTENING	1327.	0.5210
SETTLEMENT	338.	0.1327
WOOD INDUSTRIES	19.	0.0075
RECREATION	168.	0.0660
INCENDIARY	195.	0.0766
PUBLIC PROJECT	20.	0.0079
MISCELLANEOUS KNOWN	59.	0.0232
MISCELLANEOUS UNKNOWN	23.	0.0090
RAILROAD	21.	0.0082
TOTALS	2547.	1.0000

FOREST VISIBILITY SUMMARY

VISIBILITY IN MILES	NUMBER OF DAYS	PROBABILITY FOR EACH CATEGORY
0	337.	0.0441
5	998.	0.1305
10	636.	0.0831
15	1176.	0.1537
20	1521.	0.1988
25	2982.	0.3898
TOTALS	7650.	1.0000

MAY AVERAGE FIRE SIZE AT DISCOVERY 64.36 ACRES
AVERAGE FIRE SIZE AT DISCOVERY EXCLUDING MAY FIRES 29.62 ACRES

PROTOTYPE FOREST FIRE DETECTION DESIGN MODEL

FOOTNER FOREST

DESIGN ALTERNATIVE - - - - - - - - - - - - - 19 TOWERS-FLY WEATHER OR CAUSE

TOWER DISCOVERY SUMMARY

TOWER CODE	TOWER NAME	NUMBER OF FIRES DISCOVERED	PERCENT OF TOWER DISCOVERIES	PERCENT OF TOTAL FIRE DISCOVERIES
1	YATES	70.	0.07	0.027
2	STEEN RIVER	64.	0.07	0.025
3	AMBER	62.	0.06	0.024
4	ADAIR	63.	0.06	0.025
5	ZAMA	98.	0.10	0.038
6	BASSET	79.	0.08	0.031
7	WATT MOUNTAIN	100.	0.10	0.039
8	RAINBOW	44.	0.04	0.017
9	WHITE SANDS	39.	0.04	0.015
10	PONTON	81.	0.08	0.032
11	FOGGY MOUNTAIN	54.	0.06	0.021
12	LAMBERT CREEK	38.	0.04	0.015
13	BUFFALO	71.	0.07	0.028
14	WADLIN	67.	0.07	0.026
15	PANNY	3.	0.00	0.001
16	TALBOT LAKE	13.	0.01	0.005
17	BISON LAKE	5.	0.01	0.002
18	HAWK HILLS	13.	0.01	0.005
19	JEAN LAKE	16.	0.02	0.006
	TOTAL	980.	TOTAL 1.00	TOTAL 0.385

PERCENT OF TOTAL FIRES DISCOVERED BY TOWERS 0.385

PROTOTYPE FOREST FIRE DETECTION DESIGN MODEL
FOOTNER FOREST
DESIGN ALTERNATIVE - - - - - - - - - - - - - 19 TOWERS-FLY WEATHER OR CAUSE

AIR ROUTE DISCOVERY SUMMARY

AIR ROUTE NUMBER		NUMBER OF FIRES OCCURRING ON ROUTE		PERCENT OF AIR ROUTE OCCURRENCES		PERCENT OF TOTAL FIRE OCCURRENCES
64.		49.		0.03		0.02
21.		470.		0.28		0.18
22.		375.		0.22		0.15
23.		334.		0.20		0.13
24.		460.		0.27		0.18
	TOTAL	1688.	TOTAL	1.00	TOTAL	0.66

PERCENT OF TOTAL FIRES OCCURRING ON AIR ROUTES 0.663

AIRCRAFT DISCOVERY SUMMARY

AIR ROUTE NUMBER		NUMBER OF FIRES DISCOVERED		PERCENT OF AIR CRAFT DISCOVERIES		PERCENT OF TOTAL FIRE DISCOVERIES
64.		15.		0.04		0.01
21.		97.		0.25		0.04
22.		24.		0.06		0.01
23.		21.		0.05		0.01
24.		225.		0.59		0.09
	TOTAL	382.	TOTAL	1.00	TOTAL	0.15

EFFECTIVE PERCENT OF FIRES DISCOVERED BY AIR CRAFT 0.150

PUBLIC DISCOVERY SUMMARY

TOTAL NUMBER OF FIRES DISCOVERED BY PUBLIC 1187. PERCENT OF TOTAL FIRES DISCOVERED BY PUBLIC 0.466

TOTAL 1.001

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                    PROTOTYPE  FOREST  FIRE  DETECTION  DESIGN  MODEL
                               FOOTNER                  FOREST
DESIGN  ALTERNATIVE - - - - - - - - - - - -  19 TOWERS-FLY WEATHER OR CAUSE

                                       FIRE   IN   FUELS   SUMMARY

                     FUEL   TYPE        NUMBER OF FIRES        PROBABILITY

                    CONIFEROUS                 1050.                 0.41

                    MIXED WOOD                  619.                 0.24

                    LICHEN - MUSKEG             616.                 0.24

                    GRASS                       262.                 0.10

                                    TOTAL      2547.       TOTAL      1.00


                                 STATISTICS   FOR   THIS   RUN

XBAR            =         601826.        = AVERAGE TOTAL SEASONAL COST

VARIANCE        =    90244055040.

STD DEVIATION =           300407.

LENGTH OF CONFIDENCE INTERVAL =          40360.     AT  Z  = 0.9500

 STOP      0
12:18.19 69.276 RC=0
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